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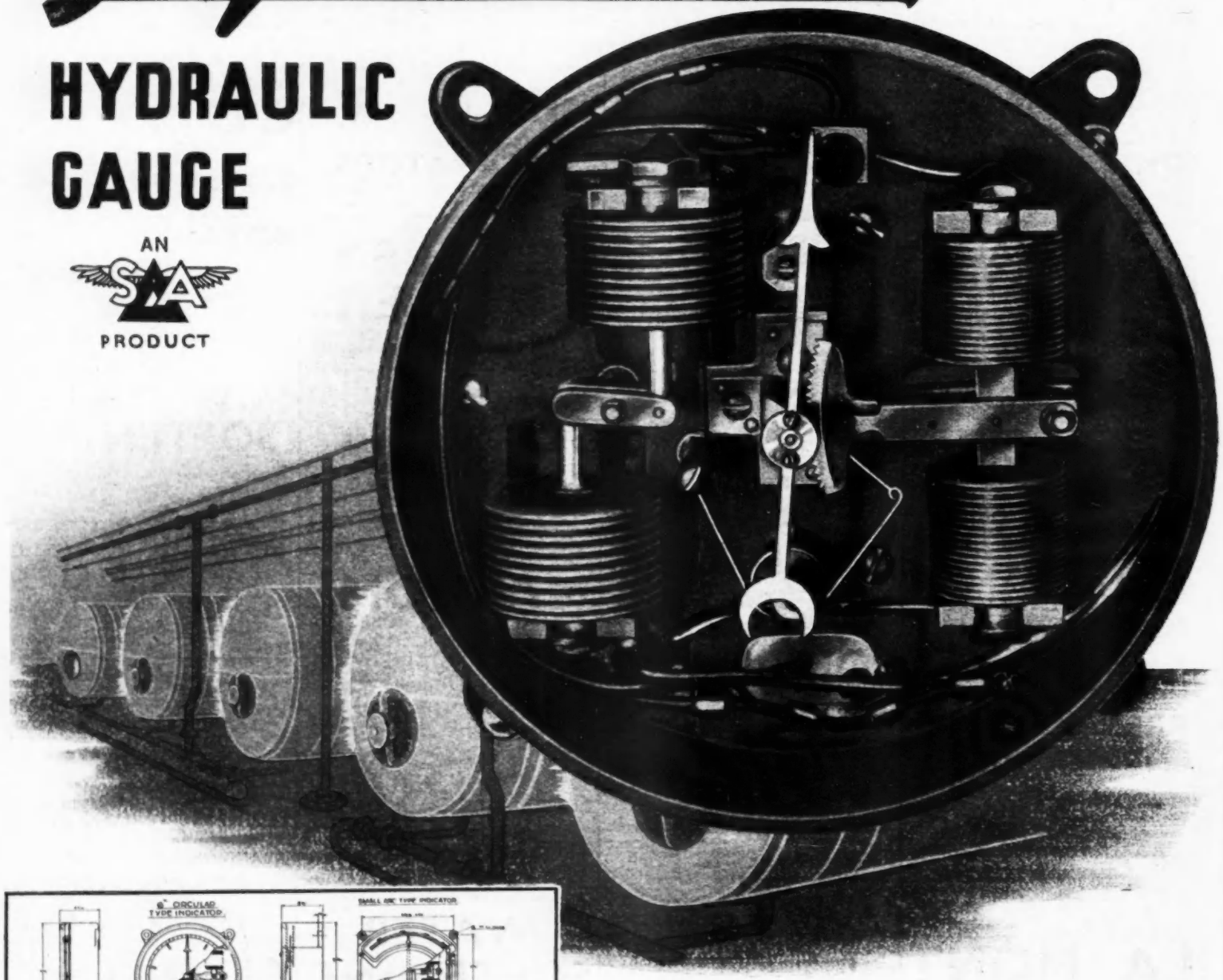

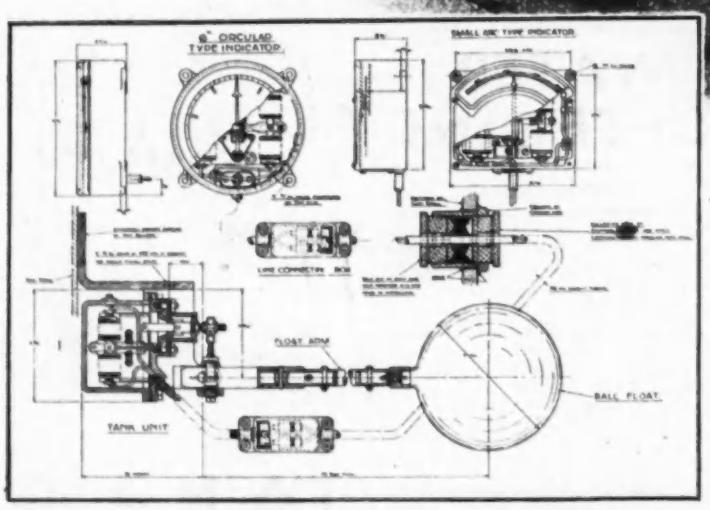

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THE CHILCOTE PUMPING STATION AND SOFTENING PLANT OF THE SOUTH STAFFORDSHIRE WATER-WORKS COMPANY.

UNDER the South Staffordshire Waterworks Acts, 1932 and 1936, the South Staffordshire Waterworks Company obtained powers to put down three further pumping stations for the purpose of meeting the constantly increasing demand for water in their area of supply. The three stations—Kinver, Seedy Mill and Chilcote—obtain water from the underground sources in the New Red Sandstone formation, and have now been brought into commission. With these additional stations, the total number of main pumping stations forming the company's sources of supply is now twenty-two. Practically the whole of the available underground sources of supply within the company's area of jurisdiction have been appropriated by the company, and as the surrounding underground sources of supply have already been assigned to adjoining water authorities, the company obtained powers under the South Staffordshire Waterworks Act, 1939, to utilise the available water from the River Blithe by the construction of an impounding reservoir in the River Blithe valley, having a capacity of 2,000 million to 2,500 million gallons, with pumping and purification works at Seedy Mill designed to deal ultimately with 10 million gallons a day. As Chilcote pumping station is one of the last three stations to be constructed, and there are certain peculiarities in the nature of the water obtained from this station, the special design of the pumping and purification works should prove of considerable interest to the engineering profession.

The construction of Chilcote pumping station, illustrated in Figs. 1 to 19, on this page, on pages 453 and 462, and on Plate XXIV, was sanctioned under power obtained in the company's Act of 1932. The working of the station is subject to certain conditions imposed by Parliament for the protection of wells and other sources of supply within a radius of two miles from the station. In order to obtain definite information regarding the ultimate effect of pumping operations, eight tube wells, lined with 2-in. internal diameter steel tubes, were driven around the site. Four of these wells were situated on a radius of ¼ mile from the station, and approximately, north, south, east and west, and the remaining four on a radius of ½ mile in the same directions. The depths of these wells vary to a maximum of 27 ft. below ground level. It was eventually discovered that one of the wells on the ½-mile radius situated on high ground south of the site contained little or no water even after deepening, and it was, therefore, abandoned. A trial boring was first put down to prove the geological formation on the site of the proposed Chilcote pumping station. This boring was put down from ground level to a depth of 76 ft., when a 15-in. guide tube, 30 ft. in length, was inserted, and through this guide tube 76 ft. of 12-in. diameter solid-drawn lining tubes were fixed. The trial boring continued to a total depth of 805 ft. 8 in., being 11½ in. in diameter, unlined. The borehole penetrates the Lower Keuper Sandstone, Bunter Pebble Beds and Permian Breccia. The water table in this trial boring was found at only 1 ft. 11 in. below ground level. A short pumping test was carried out on the trial boring and a yield of 27,000 gallons per hour obtained, the water falling to 47 ft. below ground level. From an examination of depth samples taken during the test, it was found that there was an excessive chloride content in the bottom water (794 ft.) where the permanent hardness was also very high. Experiments were tried with fluorescine during the pumping to ascertain the flow of water in the borehole. These experiments, however, were not a success owing to difficulties produced by the method of pumping employed. It was, therefore, decided to seal out the Keuper Sandstone and Marls in the upper part of the boring by means of a 9⅞-in. solid-drawn steel lining tube to a depth of 78 ft. below ground level, and to cut off the lower water of the borehole by placing a 22 ft. 6 in. long neat-cement plug between the depth of 703 ft. 6 in. and 726 ft. below ground level. A second pumping test was carried out, which resulted in an average decrease of approximately 1·6 parts per 100,000 in total hardness and 2·0 parts per 100,000 in permanent hardness. Typical details of the final water obtained from each test are shown in the accompanying table.

Fig. 1.

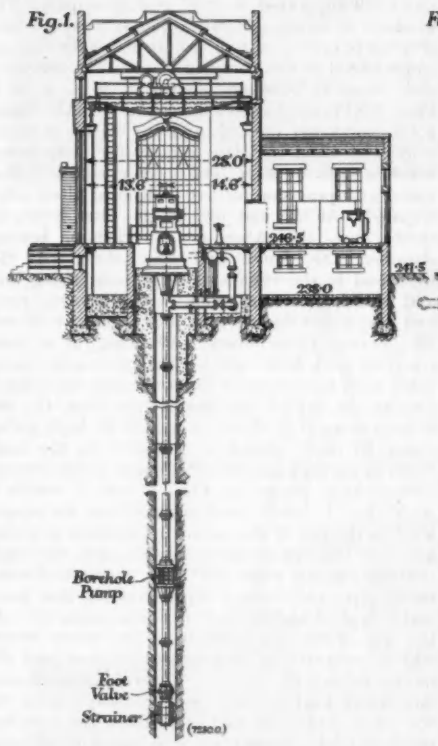
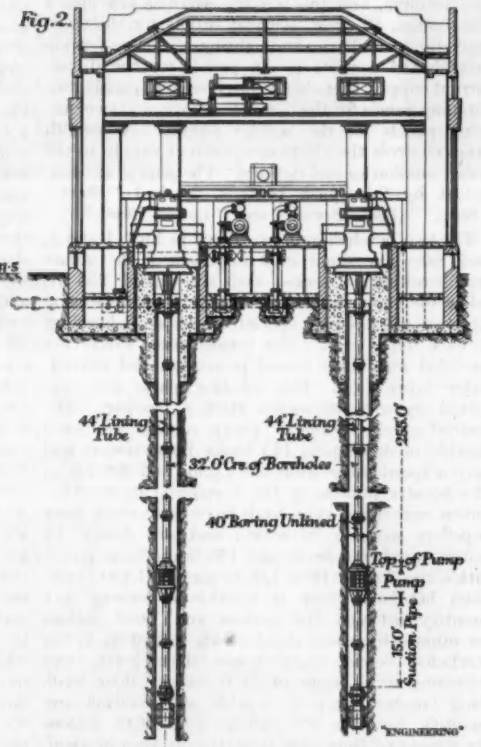


Fig. 2.



		First Test. (November, 1931).	Second Test. (December, 1931).
Alkalinity, parts per 100,000		24·2	24·5
Chlorides	do.	11·70	7·22
Permanent hardness	do.	19·4	17·2
Total hardness	do.	42·8	41·1

Although the average rate of pumping was decreased from 27,000 gallons per hour in the first test to 26,000 gallons per hour in the second test, it is interesting to note that the average water level fell from approximately 47 ft. to 50 ft. below ground level, probably due to the effect of placing the cement plug. Lime and sulphate constituents were also much reduced, while the magnesia remained unaltered.

The main boreholes, shown in Figs. 1 and 2, differ in design and construction. They are located at 32 ft. centres and approximately 40 yards west of the trial boring. The strata were found to correspond fairly closely with those proved in the trial boring, cores from which are shown in Fig. 3, page 453. Both boreholes are carried down to a depth of 695 ft. In No. 1 borehole, 44-in. internal diameter solid-drawn steel lining tubes extend from ground level to a depth of 180 ft., passing through 33 ft. of 48-in. internal diameter solid-drawn steel guide tube; 44-in. internal diameter perforated-steel lining tubes extend from 180 ft. 6 in. to 297 ft. 6 in.; 23-in. diameter unlined boring from 297 ft. 6 in. to 525 ft.; and 21-in. internal diameter perforated steel lining tubes from 525 ft. to 695 ft. A commencement was made on this borehole on April 19, 1933, by Messrs. C. Isler and Company, Limited, Bear-lane, Southwark-street, London, S.E.1, who were also responsible for the sinking of the trial boring and borehole No. 2. The method of construction was as follows:—A timbered shaft, 9 ft. square in cross-section, was sunk to a depth of 8 ft., and inside this a 52-in. diameter shaft was sunk to a depth of 35 ft. 6 in. below ground level. Two 48-in. diameter solid-drawn steel guide tubes, each 16 ft. 6 in. long, were welded together, lowered into position in the borehole, founded on a cement plug, centred, and finally cement grouted into position. During the whole of these operations, pumping was necessary to keep down the level of the water in the borehole. After the completion of concreting in the 8-ft. square shaft, a 48-in. diameter boring was carried down by the rotary method through the cement plug to a depth of 54 ft. below ground level. A 47-in. diameter boring was continued to a depth of 118 ft. 6 in. below ground level, a check for verticalness at 58 ft. 6 in. revealing that the borehole was satisfactory. A pilot hole, 23 in. in diameter, was then driven to 152 ft. 6 in. below ground level and later enlarged to 47 in. in diameter, the remainder of the 47-in. diameter boring being completed by the rotary method to a total depth of 297 ft. 6 in. below ground level. Further plumbing tests indicated that although the borehole had not been sunk truly vertical, the deviation made was well within the limits of 3 in. in the first 300 ft. allowed in the specification. The 44-in. internal diameter perforated steel lining tubes, ⅜ in. thick, were placed in the borehole in the following manner: The tubes were delivered to the site in eight lengths, each of 14 ft. 7½ in. The first length, having a steel shoe welded on, was lowered into the top of the borehole and firmly held with clamps, while the second tube was electrically-welded to it, as shown in Fig. 4, page 453. The weld was made in an external triangular groove formed by one abutting edge of the tube being left square and the other chamfered. After welding, each joint was thoroughly cleaned and well coated both inside and outside with bituminous solution, each tube being lowered as far as necessary to form the next weld when the bitumen had set. In this manner a total range of 117 ft. of perforated lining tube was welded, great care having been taken to ensure accurate alignment. The top tube had a 47-in. outside diameter steel plate, 2 in. wide by ⅞ in. thick, welded on to the upper end, to enable it to be centralised in the borehole. A special pre-cast cement plug was then placed in the top of the tube, and both were lowered on to the bottom of the borehole (297 ft. 6 in.) and carefully aligned. A quantity of china clay was lowered on to the plug and well puddled around the sides. To complete the 44-in. internal diameter lining, 12 solid-drawn lining tubes, each 15 ft. long and ⅜ in. thick, were welded together in the same manner as the perforated tubes, and lowered down the hole to within 4 ft. of the top of the china clay. Approximately 3 ft. of neat cement grout was then lowered down the borehole, and before it had time to set, the solid steel lining tubes were lowered down through it, and on to the top of the cement plug. As the cement plug extended 6 in. above the top of the perforated tubes, a corresponding gap was

left between the solid and perforated lining tubes. The cement was then allowed partially to set, while the tubes were lined up, after which the annular space between the solid lining tubes and the boring was grouted up by pouring the grout down ¾-in. diameter tubing lowered down the hole. This tubing was gradually withdrawn as grouting proceeded, so that its end was just above the level of the rising grout. This operation was carried on continuously until the annular space and any cavities which might have existed in the strata were completely filled. All grout was composed of neat Ferrocrete cement with sufficient water to produce a smooth fluid consistency. After allowing the grout to set for seven days, a 43-in. diameter boring was resumed through the cement plug. The core thus obtained was recovered after dropping to the bottom of the hole. The borehole, 23 in. internal diameter below 297 ft. 6 in., was sunk to its full depth of 695 ft. by means of the rotary method. Good progress was made to a depth of 403 ft., when it became necessary to trim the hole before continuing. After trimming, fair progress was maintained, until the loose Conglomerate Beds were reached at 512 ft. and again at 624 ft. These beds delayed boring considerably, but by August 1, 1934, the boring was completed, and the 22-in. internal diameter perforated steel lining tubes, which were to be placed in the bottom of the hole, were ready for welding. For this 23-in. diameter portion of the boring, the contract specified a maximum deviation of 1 in. per 100 ft., measured from the centre line of the boring at its commencement at 297 ft. 6 in. below ground level. On plumbing the completed hole, however, it was found to follow a very tortuous line below 300 ft., and it would have been impossible to lower the 176 ft. of 22-in. internal diameter perforated tubes in one section. It was decided, therefore, in order to prevent any delay in completing the boring, to lower the tubes in three sections, and to cut off the end of the first tube at an angle to facilitate lowering. Each section contained three tubes, each tube approximately 18 ft. 10¾ in. long, welded together in the same manner as the previous sets of lining tubes. These sections were lowered into the hole as they were completed, care being taken to see that they butted on to each other to form a continuous lining from 525 ft. to 695 ft. below ground level.

The yield test on No. 1 borehole was commenced on August 29, 1934, using a pumping plant consisting of a Sulzer three-cylinder, two-cycle, airless-injection engine, driving a Sulzer vertical-spindle, eight-stage, borehole pump, coupled directly through a gearbox. The test plant is shown in Fig. 5, opposite. The foot valve was located 236 ft. below ground level, and pumping commenced at the rate of 21,000 gallons per hour. The quantity was gradually increased to 60,000 gallons per hour, at which rate it remained constant throughout the test. The water levels during the test, both in borehole No. 1 and the trial boring, fell from approximately 6 ft. 1 in. and 5 ft. 11 in., respectively, to 96 ft. 4½ in. and 46 ft. 9½ in. During the test, the pump delivered water, through a Kent Orivent meter, to a weir box on which was placed a Lea recorder. From the weir box the water ran through a lagoon and spread over the lower ground, eventually finding its way to a brook running adjacent to the site. The average daily quantity of water raised was 1,464,000 gallons. Water levels were measured at regular intervals during the test by electrical apparatus, the temperature of discharge being recorded and samples taken every six hours for chemical and bacteriological analysis. At the conclusion of the pumping test, the water level was 96 ft. 4½ in. below ground level. The recovery in the borehole was rather slow, taking 75 minutes to reach a level 20 ft. below static head. The total hardness of the water was found to be 40·0 parts per 100,000, of which 16·2 were permanent. During the progress of the test, the tube wells at ¼-mile and ½-mile radius were not appreciably affected, neither was any depletion observed at Chilcote (¾ mile north) nor at No-Man's Heath (1 mile south). A complaint was received from a point 1½ miles north, however, and after investigation it was decided to conclude the test at 9 p.m. on September 5, after a continuous seven days' run. The second borehole was commenced immediately, 32 ft. south from borehole No. 1, on September 12, 1934, and completed on October 3, 1935.

The pumping plant shown in Figs. 1 and 2, page 451, includes duplicate electrically-driven centrifugal pumps, supplied by Messrs. Mather and Platt, Limited, Manchester, Messrs. The English Electric Company, Limited, being sub-contractors for the electrical equipment. The duplicate power supply (three-phase, 50 cycles, 11,000 volts), is provided by the Leicestershire and Warwickshire Electric Power Company. In order to obtain the best efficiency with variable-speed motors on the pumps it was decided to convert the supply by means of mercury-arc rectifiers to suit direct-current motors. In the high-tension room is the high-tension switchgear, consisting of two incoming panels, one metering panel, and two outgoing panels. There are also two step-down transformers, each rated at 315 kVA, and two rectifiers, each having an output of 250 kW at 550 volts. The secondary winding supplies six-phase current at 515 volts for the rectifiers, and the tertiary winding provides a three-phase, 50-cycle, 400-volt supply for the overhead crane, auxiliaries and lighting. The low-tension switchboard consists of six panels for the direct-current supply, there being two incoming panels, two outgoing panels for the borehole pumps, and two outgoing panels for the booster pumps. A seventh panel controls the alternating-current supply to the crane, auxiliaries and lighting. The pumps are controlled by four push buttons, marked "Start," "Stop," "Raise Speed," and "Lower Speed."

The two borehole pumps, shown in Figs. 1 and 2, each have five single inlet impellers of the volute type working in series, and are placed 255 ft. below the engine-house floor level. The suspension pipes are of steel with special bronze shaft bearings at each pipe joint. The transmission shafts are provided with shaft tunnel protection and filtered-water lubrication. The rotating parts are supported by a water-cooled Michell bearing. The vertical-spindle borehole pump motors are each capable of developing 145 brake horse-power, and have a speed range from 600 r.p.m. to 1,000 r.p.m. The booster pumps, of the horizontal electrically-driven centrifugal type, each have three single-inlet impellers working in series, and are driven by motors capable of developing 135 brake horse-power with a speed range from 1,050 r.p.m. to 1,450 r.p.m. Each borehole pump is capable of raising any quantity between 700 gallons and 1,042 gallons per minute from any depth down to 270 ft. in the boreholes below engine-house floor level, and delivering to a height of 50 ft. above floor level. Each booster pump is capable of delivering any quantity between 700 gallons and 1,042 gallons per minute to Outwoods Reservoir at Burton-upon-Trent, against a head of 215 ft. to 355 ft., including pipe friction.

The lift of 50 ft. above floor level of the borehole pumps enables water to be pumped to the softening plant. At first, the borehole pumps delivered through six filters, which were temporarily erected for the removal of iron and manganese from the raw water, and discharged into the treated-water tank from which the booster pumps take their suction. Now that the softening plant is in commission, the borehole pumps pump directly into the deposition tank. The delivery main to Outwoods Reservoir is at a higher altitude at Mount Pleasant than at the reservoir. In order to keep the main charged in case of a stoppage at Chilcote, the booster pumps deliver against Winshill Tower head, which ensures a feed back to keep the main filled. The head on the booster pumps is, therefore, higher than that necessary to feed Outwoods Reservoir, and to control the pressure to Outwoods Reservoir the control-valve house has been constructed. This house contains duplicate pressure-sustaining and pressure-reducing valves. The pressure-sustaining valve does not allow water to flow to Outwoods reservoir until the booster pumps at Chilcote have built up the pressure to reach Winshill Tower. When Winshill pressure is attained, the pressure-sustaining valve opens and allows the water to flow through the pressure-reducing valve, which reduces the pressure on the Burton-upon-Trent side to a safe value for the existing mains and permits sufficient to flow over the standpipe into Outwoods Reservoir. The pumps at Chilcote are so arranged that the borehole and booster pumps can work in series and pump to Outwoods without passing through the water-softening plant, if necessary; also, either borehole pump can work with either booster pump, as desired. The basement under the engine room is utilised for the pumping mains and valves, while the portion under the high-tension room, office, lavatory and workshop is utilised as spare-part stores, heating chamber and oil stores. The main pump room is provided with a 25-ton overhead crane fitted with hand traversing gear and electric two-speed hoisting gear.

The pumping station building is constructed chiefly of brickwork faced with "Rustic" bricks, supplied by Messrs. Morris, of Oldbury, with white Hollington stone base and dressings. It comprises the pump house, 54 ft. by 28 ft., with basement, also transformer house, workshop, office, lavatory, heating chamber, and stores. The roof is constructed of pitch-pine boarding, finished with Welsh slates, all supported on steel roof principals. The windows at either side of the pump room are constructed to open so as to give easy access for delivery and removal of the pumping plant. The filtration, and chemical buildings, shown in Figs. 6 to 9, Plate XXIV, are designed in keeping with the engine house previously erected, and are chiefly in brickwork with hand-made tile roof to the filter house, which is 83 ft. by 30 ft., and accommodates 12 filter units, with provision for two additional filters when required. At the east end of the filter house, as shown, are the laboratory, workshop, heating chamber, CO_2 house and coke store. At the west end is the chemical house, comprising lime and chemical dosing room, with conveyor room and lime-slaker room above, and having an electric lift serving these floors. Adjoining is a lime-receiving yard, under which is the lime crusher room, fitted with lime elevator for conveying the crushed lime to the top of the lime-storage bins, the size of each being 9 ft. diameter and 20 ft. high, giving about 30 days' capacity. Adjacent to the tank, between the tank and the filter house, is the concrete access shaft, shown in Figs. 6 and 7, which is 10 ft. 5 in. by 16 ft., and extends from the ground level to the top of the tank. In addition to giving access to the roof of the deposition tank, this shaft contains the raw-water inlet pipe, the treated-water outlet pipe, the delivery pipes from the lime plant and CO_2 plant and the various waste pipes, etc. At the top of the access shaft is the access house, which contains the lime-measuring gear and the motors driving the mixers. From the access house, two doors lead to the open gangway round the top of the CO_2 channel, and from the gangway entrance to the channel can be obtained for cleaning, etc., through manholes, and to the conveyor room at the top of the lime-storage bins. A third door in the access house leads to an enclosed gangway over the inlet channel to the motor room over the flocculating flume. This room, which is shown in Fig. 6, contains the motors driving the flocculator and the scraper. Access is gained to the tank by a ladder from the top of the CO_2 channel and from two manholes through the wall near the bottom of the tank. The whole of the tank, channels, access shaft and flocculating flume is constructed in reinforced concrete. The structure is built on the system of splitting it up into a series of units by planes of stoppage which, in the water-retaining portions, are treated with a Bitumastic compound to prevent leaking. The wall of the tank is separated from the floor by a sliding joint consisting of a Bitumastic paint. To prevent leakage, there is a circumferential joint composed of corrugated copper sheets and plastic bitumen penetrating into both the wall and the floor. The deposition tank in course of construction is shown in Fig. 10, the same tank, with the CO_2 house in the foreground, is shown in Fig. 11, and a view showing the circumferential reinforcement bars and part of the concreted inside face of the tank is given in Fig. 12, all on Plate XXIV. At the west end of the filter house are the reinforced-concrete sedimentation tanks for dealing with the wash water from the filters; also the pump house containing the pumps for returning the clear water, after sedimentation, to the deposition tank. Four cottages have been constructed to house the com-

THE CHILCOTE PUMPING STATION.

MR. FRED. J. DIXON, M.INST.C.E., M.I.MECH.E., ENGINEER-IN-CHIEF.

FIG. 3. CORES FROM NO. 1 BOREHOLE.

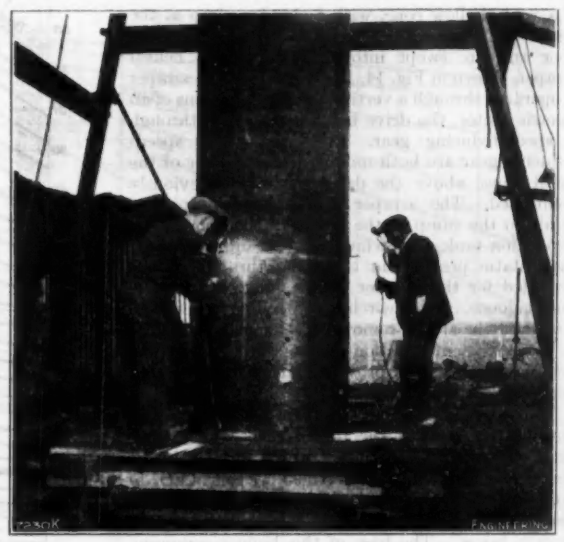


FIG. 4. WELDING OF LINING TUBES.

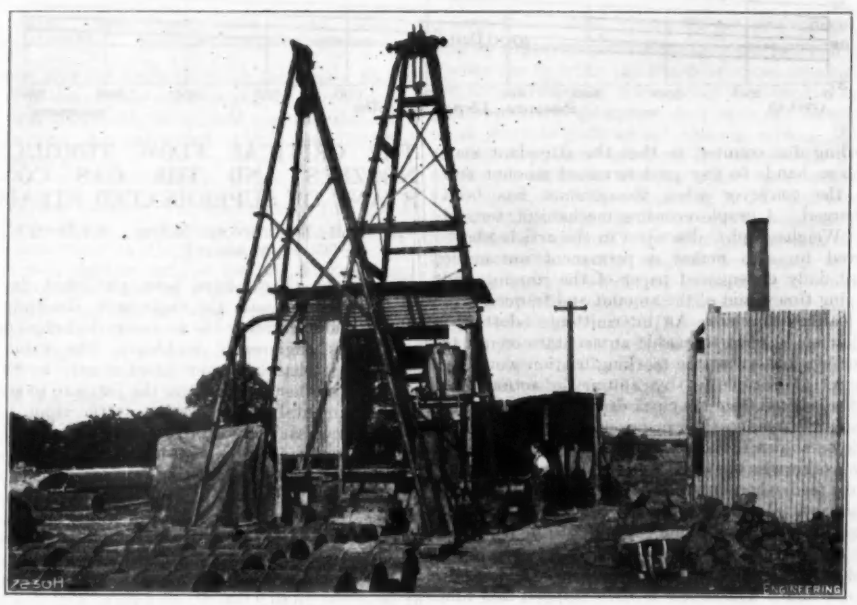


FIG. 5. BOREHOLE TEST PUMPING PLANT.

pany's employees engaged on the works. A sewage-disposal works is provided for dealing with sewage from the cottages and other buildings.

During the early stages of the life of the plant, the volume of water to be softened is 1,500,000 gallons per day. It is, however, possible that at some time in the future the output of the station may be increased to 2,000,000 gallons per day. The type of pumping plant installed at Chilcote is such that considerable variation in the output of the borehole pumps is made possible by the system of control adopted, the volume of water depending upon local conditions. In designing the scheme, therefore, due regard was taken of these variations, and very flexible arrangements were incorporated to allow the chemical treatment to be regulated immediately to suit such alterations in the pumping rate as may occur from time to time. A number of analyses of the water from Chilcote were made by the Counties Public Health Laboratories and by the suppliers of the plant, the Paterson Engineering Company, Limited. In general, the figures for the hardness of the water agreed very closely, but the different samples contained varying amounts of iron and manganese, due presumably to different rates of pumping and other local conditions. The iron and manganese varied considerably, one sample containing as much as 0·42 part per 100,000 of iron, but it seems that, in general, the iron is not likely to exceed 0·1 part per 100,000. Manganese varied from nil to about 0·006 part per 100,000, but it does not follow that this figure may not be exceeded under certain conditions. The treatment, in addition to neutralising the CO_2 present in solution in the water and reducing the hardness, removes the iron and manganese by reason of the very intense oxidation effected by the addition of lime to the water. Treatment of the water involves :—(*a*) The addition of lime, with or without coagulating reagents ; (*b*) thorough admixture of the lime and coagulant with the water ; (*c*) flocculation, to produce a precipitate which will readily settle ; (*d*) sedimentation or deposition of the precipitate ; (*e*) neutralisation of the caustic alkalinity in the water after deposition is completed ; and (*f*) filtration to remove any traces of suspended matter before the water is delivered into the supply mains.

The raw-water delivery main from the pumps passes through a channel beneath the floor of the filter house, and rises vertically in the access house adjacent to the deposition tank, as shown in Fig. 6. The end of the pipe terminates in a concrete launder which runs round a portion of the interior circumference of the tank. The water is delivered approximately in the centre of this launder and flows in both directions from it. At each end of the launder there is a vertical flume, which conducts the water to the bottom of the mixing chamber. The lime cream is delivered into the water as it enters the launder and the coagulant or coagulants are applied at suitable points in the launder or in the mixing chamber. Almost immediately after the addition of the lime to the water it comes under the influence of two revolving mixers or paddles, operated by electric motors through speed-reducing gears. One of these mixers is shown in Fig. 6. The motors and speed-reducing gears are placed on the roof of this portion of the deposition tank (which is also the floor of the operating room) and are readily accessible. The form of construction is such that the flow of water is compelled to pass through the area in which the mixers are working, on its way from the inlet launder to the flocculator. This ensures that the water, and the lime added to it, are brought under the effective operation of the mixers. A short covered channel conducts the water, which has now been thoroughly mixed with its softening reagents, to the flocculating chamber, the latter being constructed in the upper portion of the central drop tube of the deposition tank, as indicated in Fig. 6. A flocculator revolving at a relatively slow speed promotes the agglomeration of the particles of solid matter brought out of solution by the influence of the softening reagents, and thus produces conditions conducive to the effective and rapid precipitation of the hardness-forming salts. The motor which drives the flocculator is placed in a small room on the top of the deposition tank, as shown in Fig. 6, the drive being transmitted through a speed-reducing gear.

The equipment is arranged with a view to easy accessibility for maintenance, lubrication, cleaning and repairs. The flocculated water continues its passage downwards in the central tube of the deposition tank and from the lower end of this tube begins to rise in the tank itself, ultimately finding its way to two circumferential channels, constructed in concrete at the top of the tank, over the lips or edges of which channels the water flows. A portion of one of the channels is shown in Fig. 13, Plate XXIV. The capacity of the deposition tank, shown in section in Fig. 6, and visible in the background in Fig. 15, is 400,000 gallons. The internal diameter is 45 ft. (it is actually a little more than this in the upper portion, by reason

the arrangement of the planes of stoppage); the maximum depth of water at the centre of the floor is 45 ft. The circular outer wall slopes steeply in the bottom 10 ft., as shown in Fig. 6, and the floor which is 33 ft. in diameter internally, is in the form of a very shallow cone, with a circular sump at the centre. The deposited solids accumulate on the floor and are swept into the sump by a helical scraper, shown in Fig. 14, Plate XXIV. The scraper is operated through a vertical spindle by means of an electric motor, the drive being transmitted through a speed-reducing gear. The motor and speed-reducing gear are both mounted on the floor of the small house above the deposition tank previously mentioned. The scraper moves the precipitated solids to the sump in the centre of the floor of the deposition tank, from which they are ejected by the hydrostatic pressure in the tank, through a pipe provided for the purpose. The sludge is taken to four lagoons. The switches controlling the flocculator and the sludge-removal mechanism are placed in a convenient position in the filter house and duplicate control is provided at the top of the staircase in the access house.

The sedimented water is collected in two circumferential channels at the top of the sedimentation tank. The lime is purchased in the form of lumps containing from 90 per cent. to 95 per cent. CaO. It is delivered by motor lorries and tipped into a hopper, constructed at ground level, behind the reagent-storage house. The base of this hopper communicates with the inlet or charging mouth of a Sturtevant No. 1 rotary vertical spindle crusher, shown in position in Fig. 16, on page 462, which reduces the lime to any size required between about ¼ in. and 1 in. One side and one end of the lime-receiving house are provided with roller-blind shutters to afford the maximum convenience in delivering the lime. The crushed lime is discharged from the outlet of the crusher into the base or boot of a vertical elevator of the bucket type. This elevator raises the crushed lime and delivers it into one of two storage bins, shown in front of the deposition tank in Fig. 15, and to the left in Fig. 7, which are erected closely adjacent to the tank, the tops of the bins being level with the top of the tank. The combined capacity of these bins is equivalent to about one month's supply of lime, when the purification plant is softening 2,000,000 gallons per day. In addition to this generous storage, there is a considerable storage space available for lump lime in the lime-receiving house. A small building is constructed on the top of the lime-storage bins to protect the head of the elevator and for the operators to obtain access to the storage bins. In order to reduce to a minimum the dust escaping from the system, an electrically-operated fan is provided to draw air from the lime-storage bins. When crushing is in progress the fan is in operation, and as the system is entirely closed from the inlet of the crusher, the current of air is drawn through the crusher, up the elevator shaft and through the bins. In this way the air containing dust is delivered by the fan to a trap erected in a convenient position on top of the deposition tank. Sprays of water damp the dust and carry it down into the deposition tank. At the bottom of the hopper of each of the storage bins, there is a star wheel in a suitable housing, driven by an electric motor, with speed control. These wheels, when set in motion, cause lime to be delivered on to a conveyor belt enclosed in a steel casing. The belt, visible in Fig. 17, page 462, conveys the lime to two slaking mills in the lime-preparing house, shown in Fig. 8, Plate XXIV. On its way, the belt passes over a continuous weigher constructed by Messrs. Adequate Weighers, Limited, which integrates the quantity of lime delivered by the belt and also gives on a chart a graph of the amount weighed.

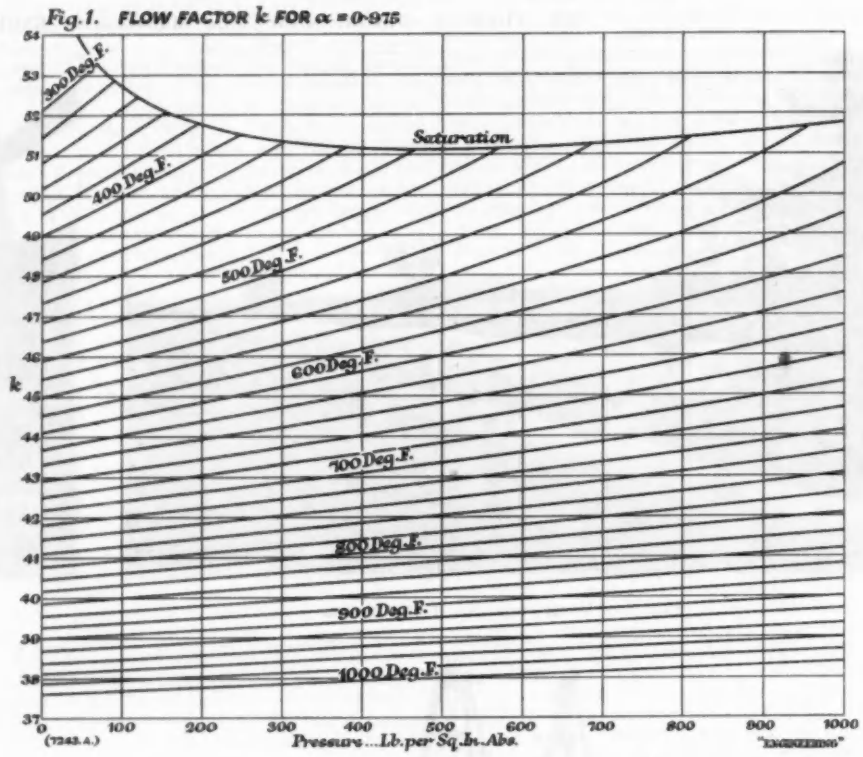
The weigher, shown in Fig. 18, page 462, is similar in principle to the one made by the same firm and described in ENGINEERING, vol. 139, page 436 (1935). A pointer traversing a graduated scale on the instrument panel indicates the rate at which material is passing at any moment so that the attendant may control the feed rate to the conveyor. For the special duty called for by the South Staffordshire Waterworks Company, a secondary set of hands is provided on the weight-recording dial counter, so that the attendant may set these hands to any predetermined amount and stop the conveyor when the amount has been discharged. A graph-recording mechanism, termed the "Weighagraph," described in the article above referred to, also makes a permanent automatic record daily on squared paper of the running and stopping times, and of the amount and frequency of the load discharged. An intermittent "dotting" mechanism is used to enable an accurate record to be made; otherwise the marking friction would be serious. Additionally, by automatic action, the marker is lifted from the clock-driven chart when the conveyor stops, so that in no circumstances will a mark be shown if the conveyor stops with material on it; otherwise the chart could record a remarkably steady feed when in reality the material had been stationary. In operation, the attendant sets the motor in motion, and lime continues to be delivered into one or other of the slakers until the required total weight is shown by the indicator on the weighing machine. The motor is then stopped and lime delivery ceases. Sufficient lime to produce a batch of cream of lime has then been delivered into the slaker and the conveyor will remain idle until the next batch is required. Each slaker is a steel tank, shown in Fig. 18, circular in plan, about 6 ft. or 7 ft. in diameter and about 4 ft. 6 in. deep. The upper half of the depth is occupied by a revolving basket or perforated tray. The lime is delivered into this portion and is submerged in water. While slaking is going on, the basket is revolved by an electric motor, and when the batch has been completely slaked it is allowed to run by gravitation into the lime storage tanks on the floor beneath the slaker, shown in Fig. 19, page 462.

(To be continued.)

SLIDE FILMS OF ARC-WELDING TECHNIQUE.—A new slide film has been prepared by the Lincoln Electric Company, Limited, Welwyn Garden City, Herts. This constitutes an addition to the series lent, with the necessary projector, and accompanying letterpress, to technical schools, engineering societies and private firms for lectures. The new film is entitled "Better Products and Lower Production Costs with Modern Arc-Welding Technique," and, we understand, illustrates the various types of arc and the machine settings necessary for different welding applications.

CRITICAL FLOW THROUGH NOZZLES.

Fig. 1. FLOW FACTOR k FOR $\alpha = 0{\cdot}975$



THE CRITICAL FLOW THROUGH NOZZLES AND THE GAS CONSTANT OF SUPERHEATED STEAM.

By J. R. FINNIECOME, M.Eng., M.I.Mech.E., M.Soc.C.E.

NUMEROUS charts have been published during recent years to assist the engineer in determining quickly and accurately the necessary technical data on various engineering problems. The value of such simple charts is appreciated mostly by those who have neither the time nor the patience to study the fundamental facts, or who, at the time, have not the necessary literature to examine and study the problems more closely. Although many exhaustive papers with interesting curves have been published on the critical flow of steam through nozzles, the accompanying fundamentally new charts relating to superheated steam should be of value to engineers who are anxious to know quickly and accurately the critical flow of steam through nozzles at pressures up to 2,000 lb. per square inch absolute, and temperatures up to 1,000 deg. F., without using the steam tables, by simply reading from the charts the flow factor corresponding to the various pressures and temperatures. By multiplying the flow factor obtained in this way by the absolute pressure before the nozzle and the minimum throat area of the nozzle, the quantity of steam flowing through the nozzle is obtained.

Applying Callendar's well-known formula for the critical flow of superheated steam through a nozzle having a throat area f and a discharge coefficient α, we get:—

$$G_1 = 1{,}135{\cdot}8\ \alpha\ .\ f\ .\ \sqrt{\frac{p_1}{v_1}},$$

where G_1 is the critical flow of superheated steam through the nozzle in lb. per hour, p_1 the pressure before the nozzle in lb. per square inch absolute, and v_1 the specific volume before the nozzle in cub. ft. per lb. The quantity G_1 can also be expressed very simply as:—

$$G_1 = k_1\ \alpha\ .\ f\ .\ p_1,$$

where k_1 is the flow factor for a discharge coefficient $\alpha = 1{\cdot}0$. Assuming $\alpha = 0{\cdot}975$, we get:—

$$G = k\ .\ f\ .\ p_1.$$

The values for the flow factor based on $\alpha = 0{\cdot}975$ are represented graphically as a function of the

CRITICAL FLOW THROUGH NOZZLES.

Fig. 2. FLOW FACTOR k FOR $\alpha = 0{\cdot}975$

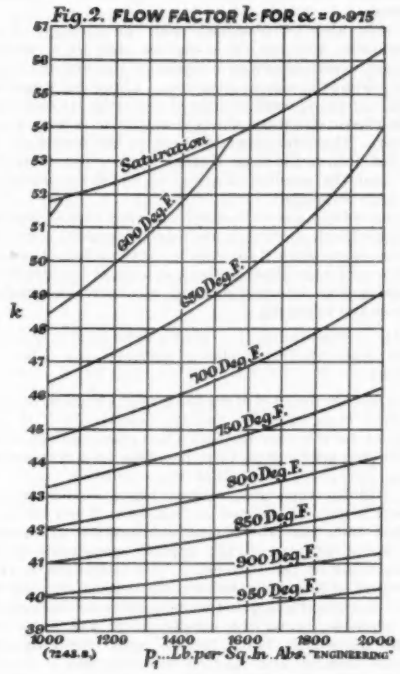
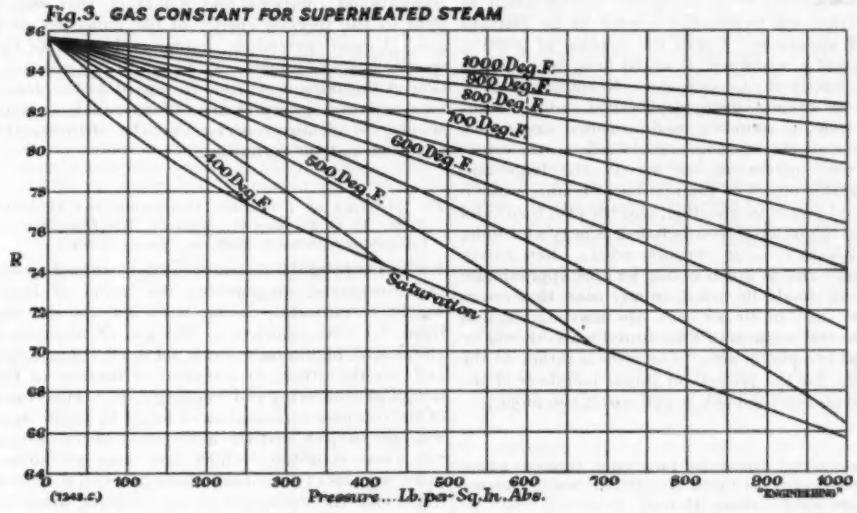


Fig. 3. GAS CONSTANT FOR SUPERHEATED STEAM



pressure and the temperature in the charts Figs. 1 and 2, on this and the opposite pages. For a specific discharge coefficient, the critical quantity through a nozzle can be calculated from the following expression :—

$$G_1 = 1{\cdot}0256\, k \,.\, \alpha \,.\, p_1.$$

A typical example will demonstrate the use of these two charts. Assuming, for example, for the inlet conditions at the nozzle, $p_1 = 500$ lb. per square inch absolute and $t_1 = 800$ deg. F., the chart, Fig. 1, gives a value of $k = 41{\cdot}26$, and thus the critical flow per hour per square inch of nozzle area and for $\alpha = 1{\cdot}0$ is :—

$$G_1 = 1{\cdot}0256 \times 41{\cdot}26 \times 500 = 21{,}158 \text{ lb. per hour per square inch.}$$

This is not only an extremely rapid method, but also an accurate means of determining the quantity of steam flowing through a nozzle. The flow factor for superheated steam and the discharge coefficient $\alpha = 0{\cdot}975$ can be read from Fig. 1, for pressures up to 1,000 lb. per square inch absolute and 1,000 deg. F., and from Fig. 2 from pressures of 1,000 lb. up to 2,000 lb. per square inch absolute.

The value of the gas constant at various steam conditions up to 1,000 lb. per square inch absolute and 1,000 deg. F., is indicated as a function of the pressure in lb. per square inch absolute, and the temperature in deg. F. in the chart, Fig. 3. The value R is based on the general equation :—

$$R = \frac{144\, p \,.\, v}{T},$$

where p is the pressure in lb. per square inch absolute, v the specific volume in cubic feet per lb., and T the absolute temperature in deg. F. The gas constant enables the specific volume to be obtained without using steam tables. The flow factor k and the gas constant R have been calculated from the data published in *Callendar's Steam Tables*. These charts show the variation of the flow factor and the gas constant with the pressure and temperature.

NON-UNIFORM YIELDING IN METALS DURING A TENSILE TEST : ADDENDUM.—With reference to the article by Dr. C. F. Elam on the above subject, published in our issue of March 29 last, on page 325, Dr. Elam has drawn our attention to a paper by Professor E. N. da C. Andrade, F.R.S., published in the *Proceedings of the Royal Society* A. 1910, vol. 84, page 1, in which he described sudden extensions in copper and referred to them as "copper quakes." We should also point out that an error appears in the footnote to the third column on page 326. The name Bowen, F. P., should be Bowden, F. P.

LITERATURE.

"Verbal" Notes and Sketches for Marine Engineer Officers. By J. W. SOTHERN, M.I.E.S., M.I.Mar.E. London : The Technical Press, Limited, 5, Ave Maria-Lane, Ludgate-hill. [Price, 60*s.* net, two volumes.]

THE inventor of the stereotype plate has much to answer for in tying the hands of those responsible for the revision of engineering text-books, since publishers, it would appear, look upon the scrapping of an obsolete plate as an economic crime. While in some re-publications there is very definite proof of this reluctance to sacrifice a few cubic inches of type metal, it is less apparent in the fourteenth edition of the book now under review ; though it is still difficult to justify the retention of such obsolescent matter as the original description of the Parsons turbine, which, to begin with, is referred to as "the latest and most successful development in marine engineering." The second adjective may be true, but the first is certainly out of place at the present day ; while, when a sentence occurs like "The inventor, the Hon. C. A. Parsons, M.A., F.R.S., gives the following brief description of the turbine," the use of an incorrect designation and the present tense in connection with a deceased engineer, must be admitted to give a somewhat ancient air to the account. There is, again, evidence of overlapping. On page 331 of Volume 1 there are four views of the horse-shoe type of thrust block, and on page 842 of Volume 2, four almost identical views ; and the question arises whether the first set could not have been dispensed with, particularly as there are only some 120 words of accompanying descriptions, which would well bear transference. On page 166 of Volume 1 is a full-page dimensioned drawing of a 5-ft. cross-tube boiler, while facing page 701 of the same volume is a folding plate of the same boiler, this latter drawing being accompanied by full calculations as to strength, etc. It may be submitted that, in spite of references to both in the index, a reader might conclude that the first drawing with its attendant text was the last word on the subject, and so overlook the informative matter presented with the second drawing. Other instances of space-wasting duplication might be cited.

This rather adverse criticism must not be taken as implying that "*Verbal*" *Notes and Sketches* has deteriorated from its former usefulness. On the contrary, we consider that the book is still fully entitled to the position its merits have won for it ; but constant addition without periodic excision may, in time, render it really too cumbrous for the purpose for which it was compiled. As it is, the two volumes of which it now consists are as bulky as is convenient, and the existence of such page-numbering as 1,550*z* and1,550 *cc*, adopted to avoid re-arrangement of the 1,870 pages, is liable to prove confusing. Our commendation of the work, therefore, is accompanied by a suggestion that the next edition be subjected to a much more drastic revision than has hitherto been made. With regard to the scope of the book, it may be pointed out that, although its sub-title reads "A Manual of Marine Steam Engineering Practice," a considerable amount of space is devoted to the internal-combustion engine and electrical, refrigerating, and other auxiliary equipment. Its utility, therefore, is even wider than the sub-title would indicate. The fourteenth edition meets the higher standard of the "new system" of Board of Trade examinations, and includes the author's work on indicator diagrams, previously published separately. An introduction to temperature-entropy diagrams deals lucidly with this important thermodynamical convention. Similar evidence of up-to-date additions appears in the descriptions of modern exhaust-turbine practice, such as the Bauer-Wach, Götaverken, Metropolitan-Vickers and other systems. Recent marine-boiler practice is also dealt with ; for example, the Yarrow boiler fitted with the Taylor mechanical stoker, and the Babcock-Johnson two-drum water-tube boiler. Such features as the section on "Engineering Knowledge Questions," which have proved of value in earlier editions, remain unchanged in form, though most have been revised.

Plane and Geodetic Surveying for Engineers. By DAVID CLARK. Vol. I : *Plane Surveying.* Third edition, revised by JAMES CLENDINNING. London : Constable and Company, Limited. [Price 27*s.* 6*d.*]

THIS well-known book, the second edition of which appeared in 1932 and was reprinted in 1937, has now been brought up to date again. The new edition includes a new chapter on linear measurements, dealing with the errors which may occur and the practical use of tapes, in a very thorough and useful manner. The treatment of traversing has been expanded, and this should meet a want that has long been felt by road and railway engineers working in countries which have not been triangulated. The traverse method has far greater value than is often supposed, if certain checks are applied to the work. Incidentally, the reviser might have made a little more of the method of checking on prominent lateral points. This method in rough country almost amounts to triangulation, the legs of the traverse acting as base lines, and by using several lateral points simultaneously, a fairly rigorous control can be kept on the accuracy of the traverse. One of the difficulties of traversing is the occasional unavoidable use of short legs. Angular errors in these have a disproportionately large effect on the whole traverse, and it is a sound practice to check them by extra lateral sights or even by a special closed traverse in their neighbourhood. The theory of errors has been introduced fairly freely.

Super-elevation on roads is discussed, although more might have been said of the inter-relation of camber to super-elevation. The case of a zigzag road ascending a mountain side presents parti-

cularly complex conditions. Camber, after all, is principally for drainage purposes, and is not needed when the super-elevation itself will provide drainage.

Echo-sounding is given special consideration in this edition, but no mention is made of the Marconi type of apparatus. Under the heading of plotting hydrographic soundings, it would have been well to have described Commander Macmillan's very ingenious circular graticule method, which saves much time in sounding well-measured areas. In the hydrographic section, a few words on the errors of current meters at low speeds, the large and unavoidable errors of summation of readings taken at several points in a section, and the effects of tidal currents might have been included. Chezy's formula, with Kutter's c, is recommended; but surely Manning's rule is much better for this approximate work. It should be noted, in any case, that errors of 5 per cent. or 10 per cent. are unavoidable, and that the end sections of a measured reach should be reasonably equal in area. The price is rather on the high side for the pockets of junior members of the profession, but the book is well worth the money.

Les Chaleurs Spécifiques. By PROFESSOR EDMOND BRUN. (*Collection Armand Colin*, No. 224.) Paris: Librairie Armand Colin. [Price 15 *fr.*]

THE admirable and authoritative monographs of the *Collection Armand Colin* are neither popular pamphlets nor specialist tracts. Their length affords scope for the treatment of a subject in something more than a superficial manner, and though not primarily addressed to specialists, they are written by experts; Professor Brun, for example, is a member of the staff of the celebrated Lycée St.-Louis. The attention that has been devoted in recent years to both the practical and the theoretical aspects of specific heat in Europe and America makes his up-to-date résumé particularly welcome.

At the outset, the thermodynamic relations involving specific heats are derived, in particular, those serving to relate the two main specific heats. Specific heat at constant pressure lends itself more readily to accurate experimental determination, the specific heat at constant volume being more advantageously employed in theoretical developments. The next chapter summarises the technique of calorimetric measurements, the methods to be employed depending upon whether the true or the mean specific heat is required, and upon whether an absolute or relative measurement is desired. A critical discussion of the precision to be expected in each type of experiment is included. It is emphasised that inaccuracies due to cooling corrections should be reduced to the minimum, since a major source of uncertainty in all specific-heat determinations arises from the fact that no completely heat-insulating enclosure is available. Stress is rightly laid upon the necessity of working with pure specimens.

Chapter III is devoted to the more recent and reliable experimental data relating to the specific heats of solids. The theoretical investigations concerning the specific heats of solids and their variation with temperature are next considered. As so often happens, the theoretical formulæ are considerably simplified under limiting conditions; hence the significance that attaches to specific-heat measurements at extremely low temperatures. It is in this region, in fact, that the classical interpretation breaks down and has to be replaced by the quantum interpretation as provided by Einstein, Debye and others. It would be unreasonable to expect, in a work of this size, complete derivations of all the formulæ, but the underlying assumptions are clearly set out and the route followed in the process of derivation is outlined. So many factors are involved, however, that it cannot yet be claimed that any single formula satisfactorily interprets the ensemble of the experimental findings. The complex subject of solids concludes with a chapter on specific heat anomalies, typical of which are those attributable to the order-disorder transitions exhibited by certain alloys. Chapters VI and VII deal respectively with the specific heats of real and ideal gases. The former is mainly experimental and describes the various methods whereby the specific heats of a gas at constant pressure and constant volume may be separately determined, as well as their ratio. Chapter VII is theoretical and deals exceptionally clearly with the various factors, translational, rotational and oscillatory, that contribute to the thermal energy of the molecules of a gas. A brief concluding chapter is devoted to the specific heats of liquids. Professor Brun's presentation of the present position in regard to the determination and interpretation of specific-heat data should be of direct service to the chemist, the physicist and the technician.

The Stressing of Locomotive Connecting and Coupling Rods. By G. W. MCARD. Epsom: The Draughtsman Publishing Company, Limited. [Price 2*s.* net.]

RECENT substantial increases in the sustained speeds of locomotives, emphasising the value of light-weight reciprocating parts, have led, on the one hand, to developments in the use of aluminium alloys and high-tensile steels for such components and, on the other, to a revival of interest in the design of connecting and coupling rods. On account of the complex combination of forces to which these rods are subject, and the uncertainty of forecasting the worst conditions which they may encounter, many aspects of their design have followed empirical rules and the rarity of service failures must be ascribed to the generous factors of safety commonly allowed. The fact that such allowances are arbitrary, however, implies that, as designed at present, rods may be larger and heavier than necessary, and that the potentialities of high strength/weight alloys cannot be fully realised.

In these respects, unfortunately, Mr. McArd's pamphlet does little to advance design beyond the traditional methods already in general use. The chief value of his work lies in its systematic presentation of formulæ and data whereby the design of locomotive rods, along conventional lines, is facilitated by graphical solutions of certain functions, and can be followed step by step with the assurance that most (though, in some cases, not all) of the factors requisite for safe operation are given consideration. Some account is given of the physical and metallurgical properties of alloy rod materials already in use in this country and the United States. The most instructive part of the pamphlet, however, is a fairly comprehensive treatment of the forces sustained by the unconventional rod assembly fitted to a class of Diesel-electric shunting locomotives which has already given satisfactory service.

In a few instances, the text is so condensed as to make the meaning obscure and the method difficult to follow, though the worked examples are clear and contain many suggestions useful in drawing-office practice. Perhaps the most serious defect, in that it applies throughout the whole work, is that no consideration is given to the fatigue strength of the material and the effects of surface finish and stress-concentrating features of shape. For components so typically subject to fluctuating stresses, and of which fatigue is perhaps the commonest cause of failure, it is not too much to assert that the properties of the material under fatigue, rather than under static, conditions provide the more rational basis of stress analysis.

PERMANENCE OF THE PHYSICAL PROPERTIES OF PLASTICS.*

By J. DELMONTE.

(*Concluded from page* 448.)

THE next point to consider is the relaxation upon removal of stress. If the molecular structure were such that elastic phenomena and plastic phenomena operated independently of one another, a rapid elastic recovery would ensue with no further recovery. However, such a condition does not exist, and the energy for the plastic recovery (sometimes referred to as the "elastic after effect") is derived from a portion of the elastic structure. The rate of recovery will still depend upon a coefficient of viscous impedance and a coefficient of internal friction, both co-operating to make the rate an exponential function of time. This observation has been made by other investigators. Further, when a constant deformation is maintained under loading conditions, we may expect an exponential recovery of stress.

It will also be observed that the recovery from deformation will not be complete, due to a permanent set which occurs as a result of the loss of stored energy from the elastic structure. Likewise, when the stress is great enough to exceed the proportional limit of the elastic structure, the permanent set is very much greater. Thus the permanent set in the material will be a function of the time of stress application, temperature, and the amount of stress to which the material has been subjected.

If we admit the existence of a true elastic portion of the molecule, how then are we to determine correctly its true elastic limit if the results for the whole structure are susceptible to plastic influences even at low stresses? Grouping the deformation and recovery phenomena, there is the following:

Elastic deformation (y_e) + plastic deformation (y_p) = elastic recovery (r_e) + plastic recovery (r_p) + permanent set.

If upon the removal of the load, r_p max exceeds y_p max. we have then exceeded the true elastic limit of the material, for it is only through a non-elastic deformation of the true elastic structure, resulting in a retardation of the elastic recovery, that this condition would be true. Thus, the true elastic limit of amorphous materials may be defined as follows: When stress is applied such that the elastic deformation y_e exceeds the elastic recovery r_e, the applied stress exceeds the elastic limit of the material. This definition is true regardless of how long the stress is applied, though the longer the stress is applied the greater is the difference. For example, under the conditions of the tests, the results quoted in Table I were noted for polyvinyl chloride acetate and methyl methacrylate. Elastic recovery was determined after 50 hr. and 100 hr. of applied stress, respectively.

TABLE I.

Maximum Fibre Stress.	Ratio of $\frac{y_e}{r_e}$.	
	Polyvinyl Chloride Acetate.	Methyl Methacrylate.
Lb. per sq. in.		
500	1·00	1·06
1,000	1·00	1·06
2,000	1·01	1·20
3,000	1·80	1·64

Similar relationships of y_e and r_e were observed for all of the other materials. Thus, in applying the definition of elastic limit given in the last paragraph, when y_e begins to exceed r_e at an increasing rate, the elastic limit of the material is exceeded. The longer the stress is applied, the greater will be this distinction, enabling the observer readily to determine the elastic limit of the elastic portion of the molecule. From this tabulation, we find that the elastic limit of polyvinyl chloride acetate lies between 2,000 lb. and 3,000 lb. per square inch, and the elastic limit of methyl methacrylate lies between 1,000 lb. and 2,000 lb. per square inch. To check this result, very careful measurements were made of the direct-tension stress-strain relationships of methyl methacrylate, and from these data the elastic limit of between 1,000 lb. and 2,000 lb. per square inch was verified.

Deformation Tests.—In preparing the data for the time-deformation curves, of which Fig. 2, opposite, is typical, the following procedure was adopted:—Owing to very rapid changes in deformation, following the application of the fixed weights serving as the load, a full 60 seconds were allowed to elapse before the first reading was taken. This value was assumed to be y_e (true elastic deformation). Likewise, very rapid changes in deflection occurred upon removal of load, and again 60 seconds were allowed to elapse before the first reading in the recovery curve was taken and r_e (true elastic recovery) measured. Another assumption is the designation of maximum fibre stress above each curve during the loading period, which is correct only for the true initial elastic deformation. This value of maximum fibre stress was obtained from equations (1) and (2), page 447, *ante*, and naturally will change during time. However, it serves as a comparative indication of how the loads were selected for the materials. The value will be even less significant when the true elastic structure is deformed, which is the case, for example, with cellulose acetate at 3,000 lb. per square inch maximum fibre stress. Actually, the recovery from maximum fibre stress in this one case is so great that there is a smaller separation of deflection ordinates between 2,000 lb. and 3,000 lb. per square inch than between 1,000 lb. and 2,000 lb. per square inch, as seen

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* Paper presented at the Annual Meeting of the American Society of Mechanical Engineers, held at Philadelphia, U.S.A., from December 4 to 8, 1939. Abridged.

in Fig. 2, which shows time-deformation curves for cellulose acetate taken over a period of 50 hours.

All values of deflection in the curves were measured at the end of a 5-in. simple cantilever beam which was adopted as a standard for comparison. It is not possible to compare curves of materials with different thicknesses, unless data are presented as percentages of the original deflection. Results are plotted as the " increase in deflection " for various time durations of loads. The increase in deflection over the initial elastic deformation is in fact the plastic deformation y_p. The elastic deformation was not plotted on the curves, inasmuch as it was desired to compare the plastic-deformation properties primarily, though the value may be estimated from equations (1) and (2) readily. They are also given in Table II. Further, upon the attainment of various time intervals, 50 hr. or 100 hr., the load was removed and 60 seconds allowed to elapse before the first reading in the recovery curve was taken. This reading would, of course, be a measure of true elastic recovery r_e, and further measurements denoted as recovery from total deflection are, in fact, plastic recovery r_p. The other materials tested gave similar curves. All of these data are for a given temperature of 85 deg. F.

For every material the two stages of plastic deformation were quite noticeable, more so in some instances than others, namely, where $\frac{dy}{dt}$ is changing (creep) and where $\frac{dy}{dt}$ becomes constant (cold flow). For higher values of stress, the longer is the time required to attain cold flow. The time required to attain cold flow differs considerably in the various materials. For example, methyl methacrylate attains cold flow at a much earlier period than polyvinyl chloride acetate. The fact that the cold-flow rates of methyl methacrylate are considerably smaller than polyvinyl chloride acetate would indicate that the former is to be preferred for applications involving the imposition of stress over long periods of time. On the other hand, the smaller initial deflections of polyvinyl chloride acetate occurring during the early stages of plastic deformation, would mark this material as better suited to short-time applications of stress as compared with methyl methacrylate. As a basis for comparing the creep and cold-flow characteristics of the materials, Table II has been prepared from the data furnished by the curves. For data upon casein plastics, there has been a recent survey of the elastic properties of 60 types of rennet casein.* In Table II a low ratio of plastic deformation to elastic deformation may be deemed desirable, as well as high values of the resistance coefficient R.

While insufficient types of the same materials were tested to permit a comprehensive analysis of the effect of molecular structure upon cold-flow characteristics, a few results may be reported. For example, when laminated phenolics were baked at 275 deg. F. for 24 hr. and then tested under cold flow, a marked decrease was observed, indicating, of course, that further polymerisation had removed from the molecular structure some of those elements susceptible to plastic deformation. Tests upon hot-mouled phenolics, which were prepared from more reactive phenolic constituents than those employed in the preparation of the laminated materials, exhibited less creep and cold flow than the laminated, and considerably less permanent set. While cold-flow and creep phenomena throw much light upon the relative merits of the commercially available materials, the full answer will not be realised until the effect of molecular weight, molecular orientation, and the effects of extraneous materials such as fillers and plasticisers, are fully examined under the same conditions. It is also interesting to note that plastic flow will occur in metals, even at ordinary temperatures at stresses below their elastic limit, though the ratio of plastic deformation to elastic deformation is very much smaller than with the plastics.

* C. A. Cooper and P. G. T. Hand, *British Plastics*, vol. 10, page 572 (1939).

Shrinkage of Moulded Plastics at Elevated Temperatures.—Always a factor in determining the permanency of the physical properties of the plastics is the effect of temperature upon the shrinkage of the materials. This after shrinkage occurs in addition to the normal thermal shrinkage of the materials when it is removed from the mould. Failure to take it into consideration has sometimes caused serious discrepancies in design values. It has been generally assumed that further thermal polymerisation (with certain temperature ranges) of thermoplastic and thermosetting compounds results in improved physical properties, though some exceptions have been noted. In phenolics, for example, the additional polymerisation incurred on exposure to elevated temperatures, is accompanied by internal shrinkage in the material as the phenolic constituents attach themselves to the main primary bond structure through methylene linkages.

Fig. 2.

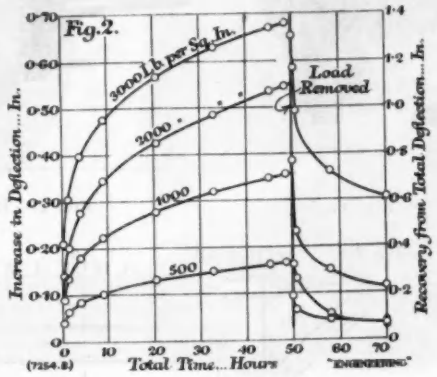
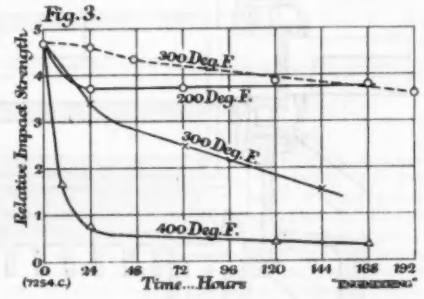


Fig. 3.



The effects of increasing temperature upon thermoplastic materials are quite marked. If they are under stress, they will distort readily, particularly as the temperature approaches their heat-distortion point. If not under mechanical stress, as for example, an electrical insulating-coil bobbin, they may be used above their heat-distortion point. It must be pointed out, however, that cellulosic products which are usually highly plasticised, will suffer a loss of plasticiser content and residual solvent, and become embrittled if exposed to excessive temperatures for too long a period. Shrinkage in moulded cellulose-acetate articles will also be due to loss of moisture content. It was noted, further, that the actual shrinkage was dependent upon which portion of the article measurements were taken, with respect to the injection gate. Cast products of polystyrene and methyl methacrylate are susceptible to further contraction during ageing, due in part to further polymerisation. In casting these materials from their monomeric form, there is a 15 per cent. to 20 per cent. reduction in volume. Tests upon articles cast of methyl methacrylate revealed that as much as 0·020 in. per inch shrinkage took place over a 24-hr. period at 200 deg. F.

Retention of Physical Properties After High-Temperature Exposure.—Consider now the physical properties of the plastics after they have returned to room temperature after being exposed to high temperatures for long periods of time. If thermoplastic in nature and they have suffered a loss of volatile materials which contributed to their impact strength, we may, of course, expect a diminution of the physical properties. For thermosetting materials, much depends upon the temperature in which the material was operating and the time at that temperature. For temperatures up to 275 deg. F., an improvement in physical properties has even been noted for some of the laminated phenolics. In Fig. 3, on this page, some interesting data are given to show the effects of high-temperature exposure upon the impact strength of laminated phenolics. Most of the results are for paper-base laminated phenolic plastics, though, for comparison, the decrease in impact strength of an asbestos-base material at 300 deg. F. is indicated by the upper dotted curve. Considerations, such as those which reveal a marked loss in impact strength after being placed in service for a certain length of time, necessitate the provision of ample factors of safety.

Effect of Moisture on Permanency of Physical Properties.—A few remarks on the effects of moisture on the physical properties will serve to emphasise this important influence on the permanency of the characteristics. Much study has been given to the changes in dimensions of various organic plastics upon exposure to moisture. This consideration of permanency is of particular importance when the moulded articles are to operate in high humidity or in water. For example, laminated phenolic bearings operating in water must be designed with adequate shaft clearance to prevent seizure when the materials swell slightly in the course of time. The author has conducted several tests in a highly humid atmosphere to illustrate the effects of high humidity upon dimensional stability of typical moulded articles, but no attempt was made to investigate thoroughly the question of moisture absorption. Particularly noteworthy was the more rapid permeation of moisture in the cellulose structure than with the moulded phenolics. Under the same conditions of test, polyvinyl chloride acetate and methyl methacrylate showed no measurable change in 48 hr.

In conclusion, it must be emphasised once again that there are many factors affecting the permanency of the physical properties of plastics. This paper has attempted to deal with the fundamental aspects of one of the most significant factors, namely, plastic deformation under stress. Further, the reader's attention has been called to other significant phenomena such as shrinkage at high temperatures, and swelling in moisture for various moulded articles, though the analysis of these conditions was not pursued as actively as for the creep and cold-flow phenomena.

TABLE II.—COLD-FLOW AND CREEP CHARACTERISTICS OF VARIOUS PLASTICS.†

Material.	At maximum fibre stress of 1,000 lb. per sq. in.					
	Total Initial Elastic Deformation (y_e).	Total Plastic Deformation (y_p).				Coefficient of Resistance to Cold Flow (R).
		At 1 hr.		At 100 hr.		
	In.	In.	Per cent.	In.	Per cent.	
			Mc.		Mc.	
Polyvinyl chloride acetate	0·407	0·020	4·9	0·106	26·0	$1·66 \times 10^6$
Polystyrene	0·370	0·012	3·2	0·090	24·0	$2·5 \times 10^6$
Cellulose acetate	0·727	0·117	16·1	0·480	66·0	$0·5 \times 10^6$
Laminated phenolic sheet (fabric base)	0·166	0·012	7·2	0·036	22·0	$9·08 \times 10^6$
Methyl methacrylate	0·446	0·030	6·7	0·065	14·6	$4·54 \times 10^6$

† Data obtained for 5-in. length simple cantilever-beam deflections, corrected for thickness of 0·090 in.

DRAFT SPECIFICATION OF ENGINEERS' FEELER GAUGES.

A FURTHER draft specification of the series of engineers' precision tools has been issued for feeler gauges under the Mechanical Industry Committee of the British Standards Institution. The specification has been prepared, in response to a request from the Institution of Production Engineers, with the co-operation of manufacturers and in close collaboration with the National Physical Laboratory. In accordance with customary practice, the draft specification, which is not yet to be accepted as a British Standard, has been widely circulated, but in case any persons or organisations interested have not yet had a copy, application for one may be made to the British Standards Institution, 28, Victoria-street, London, S.W.1. The draft specification is numbered C.F.(M.E.) 5,717, and any comments made on it should be sent to the Institution before June 17, 1940.

The main object of the specification is to establish definite grades of accuracy for feeler-gauge blades, but certain recommendations are made, in an appendix to it, in the hope of establishing some degree of uniformity in the number and thickness of blades comprising a complete gauge, present practice in this particular being extremely diverse. In whatever combination a set may be composed, however, the proposals in the body of the draft specification apply to all blades. The blades shall be made of good quality cast steel and shall be uniformly hardened and tempered to a diamond-pyramid hardness of 540 when tested with a load of 5 kg. applied for a period of 15 seconds. The approximate equivalent hardness number on the Rockwell C scale is 50. The lengths of the blades, measured overall, shall be 3 in., 4 in., 6 in., 9 in. and 12 in., all being $\frac{1}{2}$ in. wide at the heel. Blades 3 in. in length may be parallel or tapered at the option of the purchaser, those over 3 in. to be tapered towards the working end so that the width at the tip is approximately $\frac{1}{4}$ in. The tips shall have the corners rounded off and no sharp edges are to exist anywhere on the

DIRECT-COUPLED MOTORS FOR STEEL-MILL ROLLERS.

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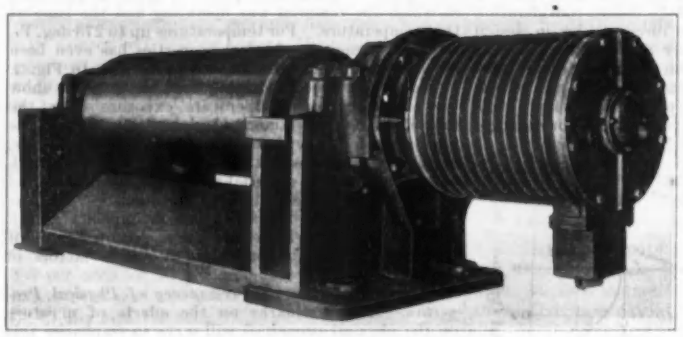


Fig. 1. Low-Frequency Motor Coupled to Roller.

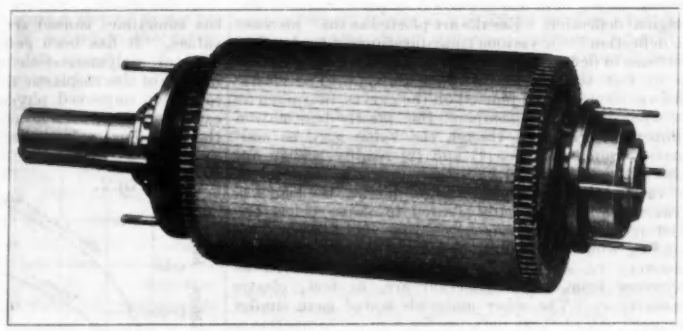


Fig. 2. Rotor of Low-Frequency Motor.

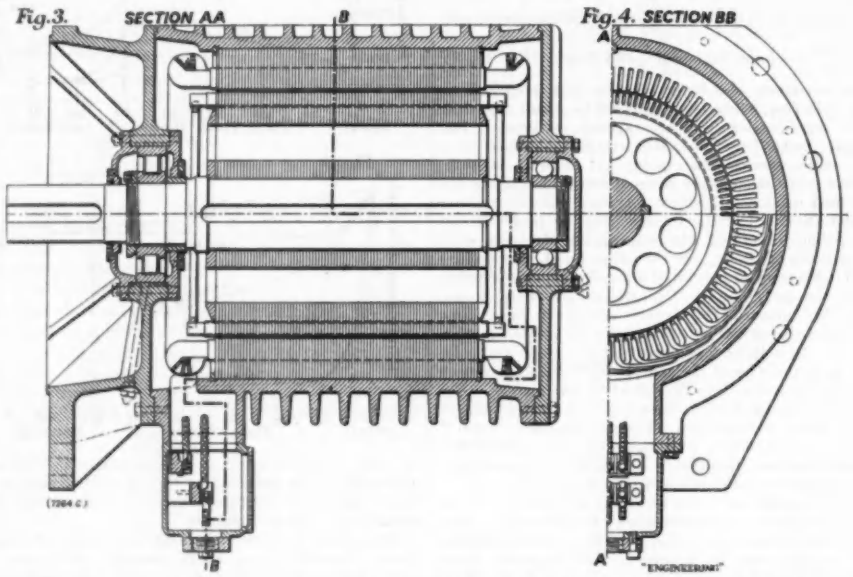
blades. The sheath shall be of mild steel with a bright finish and must fully protect the blades when the gauge is not in use. The blades shall be hinged in the sheath on a screw and nut of such a design that the blades can be removed. Each blade is to be legibly and permanently marked with its nominal thickness in thousandths of an inch and the sheath shall be marked in the same manner with the manufacturer's name or trade mark. The gauges are to be packed with the blades and sheath coated with a lanolin, or other suitable non-corrosive preparation.

It is proposed that the blades shall be made in two grades of accuracy, Grade A and Grade B, the former having the least amount of permissible error, and having the designation "Grade A" marked on the sheath. The maximum permissible error in thickness in Grade A shall vary from ±0·0002 in. for all blades of a nominal thickness ranging from 0·0015 in. to 0·012 in. inclusive, the permissible error for blades 0·015 in. thick and above shall be ±0·0003 in. For Grade B, the permissible error is ±0·0003 in. for blades between 0·0015 in. and 0·0003 in. thick. Above that the permissible error is ±0·0004 in. up to a thickness of 0·012 in., with ±0·0005 in. for the remaining thicknesses. The range of thicknesses standardised is from 0·0015 in. to 0·025 in. inclusive. The table of combinations recommended in the appendix to the specification comprises three series of blades, one series containing 15 blades, another ten blades, and the third seven blades. These series are devised so as to furnish gauges of the greatest utility with a minimum number of blades, which, in the case of the limited series, are selected so as to enable any thickness within the range of the gauge to be built up by combining two blades. Thus, thicknesses advancing by steps of 0·001 in. may be obtained in Set 15 up to 0·035 in., the range of the set being 0·0015 in. to 0·025 in. The inclusion of blades 0·0015 in. and 0·0025 in. in this set enables any thickness in half-thousandths to be obtained up to 0·0145 in. by combining two blades. The range of Set 10 is from 0·0015 in. to 0·02 in., and thicknesses up to 0·026 in. may be obtained by appropriate combinations. Set 7 has a range of from 0·002 in. to 0·015 in., but cannot be used for half-thousandth measurements. Its range can be extended to 0·021 in. by blade combination.

DIRECT-COUPLED MOTORS FOR STEEL-MILL ROLLERS.

In some modern rolling-mills individual motors for driving each roller in the roller table are being adopted, instead of one motor to drive a group through gearing. The advantages claimed for this arrangement are: The design of the roller tables can be simplified as dead alignment between the adjacent rollers is not essential. Each roller with its driving motor forms a self-contained unit, which can be replaced in a very short time if required. The maintenance cost is reduced, owing to the absence of gearing, shafting and difficulties of exact alignment. There are fewer shut-downs, as an individual roller can be cut out without interrupting the operation of the tables as a whole. The speeds of the various parts of the mill can be easily synchronised, since the roller motors are supplied from a common source and their speeds are, therefore, uniform, while the speeds can be varied by using a variable frequency converter. Finally, a higher overall efficiency is obtainable owing to the absence of gearing.

As regards the motors themselves, by designing them to run on a low-frequency supply it is generally possible to obtain the high torques required for acceleration and retardation without using specially constructed high-resistance rotors. Moreover, the size and cost of the motor can be reduced, and that of the installation is also less in spite of the fact that a frequency converter is necessary. Low-frequency motors for this purpose are manufactured by Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2. Their general appearance will be clear from Fig. 1, while their construction is shown in Figs. 3 and 4. They are made in the totally-enclosed and totally-enclosed fan-cooled types. In the latter case, the fan is situated outside the motor shell, over which it drives a continuous stream of air, the flow being assisted by a cowl. The stator shell, which is illustrated in Fig. 5, opposite, is made of cast-iron or steel, and is heavily ribbed to provide an adequate cooling surface. Its diameter is kept as small as possible and is usually less than that of the roller to which it is coupled. Floor plates can, therefore, be placed over the motor if desired. The winding consists of asbestos-covered wire, which is insulated from the stator slots by micanite. A complete fireproof construction is, therefore, obtained. Additional insulation is provided in the end windings between phases by the use of flexible strips of micanite. After the winding has been completed, the stator is dried out and while still hot is immersed in insulating varnish. Finally, the completed stator is baked.



The winding of the rotor, which is illustrated in Fig. 2, usually comprises a number of copper or bronze bars, which are oxy-acetylene welded to end rings to form a squirrel-cage winding. The bars are laid in troughs of anodised aluminium or in some cases aluminium windings die cast in one piece are used. The shaft is made of 45-ton steel and runs in ball and roller bearings, which are housed in cast-steel end brackets. One of these brackets forms the flange for securing the motor to the roller. This flange can be made to suit any standard type of roller. The terminal box is mounted on the underside of the stator frame and is designed so that the terminals are readily accessible.

As already mentioned, to reduce the starting current and provide a high starting torque a low-frequency supply is used. This supply is obtained from a converter which can be either of the constant-frequency or variable-frequency type, depending upon whether constant or variable-speed drives are required. The constant-frequency converters are usually driven by induction motors supplied from the alternating-current mains, while the variable-frequency machines, one of which is illustrated in Fig. 6, opposite, are driven by variable-speed direct-current motors. With this arrangement, the roller motors of the working tables can be started up at low frequency and rapidly accelerated or retarded by varying the speed of the converter and consequently the frequency of their supply. It is possible to supply a complete installation from one converter even when different table speeds are required, but a better cable lay-out may be secured by installing a number of converters, each of which supplies its own set of roller motors.

The control equipment for these motors is of the contactor type and is arranged for remote operation from master controllers. For each group of motors the equipment includes a triple-pole main isolating switch and two triple-pole reversing contactors. These are fitted with roller bearings and are designed for very frequent service, up to 750 operations per hour. Protection is afforded by cartridge-type high rupturing capacity fuses and no-volt relays. These relays are arranged so that they will trip the main contactors in the event of the failure of the constant or variable-frequency supply to the unit. If the relays have operated, the contactors can only be reclosed after the master controller has been returned to its off position. Where the control equipment is installed in the same building as the mill, it is enclosed in dust-proof cubicles arranged as a single switchboard, but if it is erected remote from the mill, open-type contactors can be used and the equipment can be mounted in the form of a flat-back switchboard.

DIRECT-COUPLED MOTORS FOR STEEL-MILL ROLLERS.

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FIG. 5. STATOR OF LOW-FREQUENCY MOTOR.

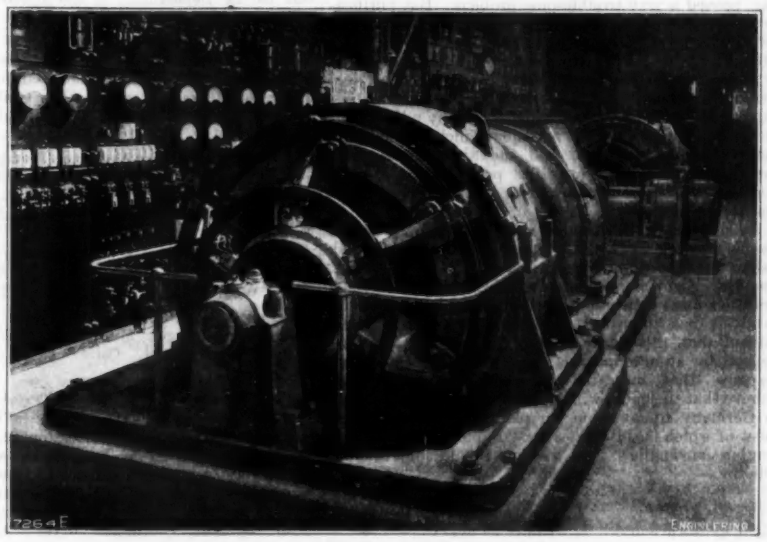

FIG. 6. VARIABLE-FREQUENCY CONVERTER.

Each pair of reversing contactors is arranged to control a group of motors. Each motor is, therefore, protected by a triple-pole iron-clad switch with fuses or a triple-pole contactor with thermal overload releases. These can be mounted alongside each motor, the main power cables, which run the whole length of the tables, being looped into connection boxes. Alternatively, the protective units can be centralised on a 'bus-bar chamber near the motors, an arrangement which has the advantage that it is only necessary to provide heavy power cable to each set of protective units, smaller cables being taken thence to the motors. The master controllers for actuating the reversing contactors are of the lever-operated steelworks pattern with forward, reverse and off positions. Contacts are provided in the off position for resetting the no-volt relays. An open-type flat-back switchboard is usually supplied for controlling the alternator of the frequency converter. This carries a triple-pole line-contact circuit breaker with over-current releases, field contactor and regulator, and the necessary instruments, which include a frequency meter calibrated in revolutions or feet per minute. On constant-frequency converters, the alternating-current driving motor is controlled by standard starting equipment, while, when a direct-current motor is used, the whole of the control equipment is mounted on the same switchboard as that for the alternator. This apparatus includes a double-pole isolating switch and circuit breaker or contactor, a shunt lock-out or time element-controlled accelerating contactors, over-current releases, a shunt regulator and a field interlocking relay which enables the motor to be run up to any pre-determined speed depending upon the shunt regulator setting. This permits the frequency of the converter to be set at any desired value. The speed of a variable-frequency converter is controlled by regulating the field of the driving motor, an operation which can be effected by means of buttons on the control desk. Alternatively, the shunt regulator of the variable-frequency converter can be connected to the speed regulator of the direct-current mill motor. This enables the frequency of the supply to the roller motors to be varied automatically with any alteration in the speed of the mill motor. The speed of the roller motors therefore varies automatically with the rolling speed.

FARADAY HOUSE SCHOLARSHIPS.—As a result of the entrance-scholarship examinations held at Faraday House Electrical Engineering College, Southampton-row, London, W.C.1, on April 3, 4 and 5, Mr. C. A. Dodd, of Staveley Grammar School, has been awarded the Faraday Scholarship of 80 guineas a year, and Mr. T. M. Palmer, of Aldenham School, the Maxwell Scholarship of 60 guineas a year. Both scholarships are tenable for two years in the College and one year in a works. Other awards comprise an exhibition of 60 guineas a year tenable for one year in the College and one year in a works, gained by Mr. T. E. C. Smith, of Staveley Grammar School; and an entrance prize of 21*l.*, obtained by Mr. D. K. Hewitt, of Taunton School.

OIL.*

By F. HERON ROGERS, M.I.Mech.E.

(*Concluded from page* 449.)

OIL enters to a large extent into the life and necessities of modern civilisation. Aviation and transport, both on land and sea, could not compete internationally without it, and, owing to its being an essential of any war activity or of defence, oil appears in the front rank of discussion in national affairs, and has on many occasions given rise to perplexing problems in political circles. Some countries are fortunate in having natural supplies, but our own country has none.

What does this absence of oil cost us? In 1938, Board of Trade figures were as follows :—

Cost of Imports, 1938.

	£
Refined petroleum, including kerosene	2,983,240
Motor Spirit	24,828,987
Other spirit	311,251
Lubricating oils	3,984,117
Gas oil	2,118,338
Fuel oil	6,554,375
Other oil	76,786
Wax	635,041
	42,482,125

Forty-two and a half million pounds is a large sum of money to export from any country. Our economists state that it creates a trading reserve of sterling abroad, which must sooner or later return here to be cashed for British goods. That argument is, in the main, sound, but we also know that such is only a partial truth and that a good part of this money comes here for American investment in our industries, but nobody can deny that this country would be in a very strong position if, out of its natural resources, it could make itself independent of overseas, and even had exportable surplus supplies. In 1920, Bergius brought forward his practical discovery that certain carbonaceous materials, under the heavy stress of high pressure and high temperature, could be made to unite with hydrogen to produce synthetic oil hydrocarbons under the influence of a catalyst. The process was developed by the I.G. Farbenindustrie in Germany, in New Jersey, U.S.A., and over here by the Imperial Chemical Industries, Limited. The plant at Billingham is a monument to chemistry and chemical-engineering endeavour.

The process would find a great number of supporters as licensees were it not for the cost of plant and of production as compared with the c.i.f. Great Britain price of competing natural oil products. In recent years, despite heavy increases in consumption and war demands, basic prices of the imported material have kept at an unprecedentedly low level. *The Board of Trade Journal* gives the following declared values of imported petroleum products :—

	Pence per gallon.				
Year.	1934.	1935.	1936.	1937.	1938.
Crude petroleum	2·0	2·0	2·0	2·3	2·2
Motor spirit ...	3·3	3·5	3·8	4·5	4·5
Fuel oil ...	1·7	1·7	1·8	2·5	2·3
Lubricating oil...	8·1	7·7	8·3	9·1	8·8

Since Bergius, there have been many research workers in the field of hydrogenation, and I only wish that space would permit recognition of many who have spent their time and fortunes in endeavouring to solve the problems of hydrogenation and reduce the cost of production. The problem which, to my vision, bids for recognition and development in this country is that originally discovered by Sabatier and Sanderens in 1902, wherein if the gaseous oxides of carbon admixed with hydrogen are passed over a catalyst (in their case nickel was used) at the relatively low temperatures of 200 deg. and 250 deg. C. and at a low pressure the following methane synthesis occurs :—

$$CO + 3H_2 = CH_4 + H_2O$$
$$CO_2 + 4H_2 = CH_4 + 2H_2O.$$

Only a small band of experimentalists have followed Sabatier and Sanderens, the later research workers having better facilities for making catalysts and understanding the catalytic problems. Following Sabatier and Sanderens were Professor Fischer and his laboratory assistants, and Dr. Tropsch, who jointly succeeded in getting liquid hydrocarbons, instead of methane, principally by decreasing the temperature of the reaction and being able to observe the reaction results in heat-controlled furnaces, where over the critical temperature, regulation could take place in fractions of a degree.

In 1925, Drs. Fischer and Tropsch actually produced light aliphatic hydrocarbons using iron and cobalt, the iron being activated with copper, and the cobalt with zinc oxide. From then until now great strides in the synthetic production of oil have taken place. To-day, Germany produces hundreds of thousands of tons of oil products over the range of petrol to wax, including a very high-class Diesel oil. Their experiments have shown that the relatively low temperature of reaction will vary with the catalyst; thus iron may require as high as 250 deg. C. and cobalt 180 deg. to 200 deg. C. The reaction is exothermic and the heat of combination must be dissipated before it has time to build up, as otherwise it becomes autotoxic. Hence the catalyst chamber must be heavily cooled and rigorous heat control maintained if economic results are to be achieved. The gases for synthesis vary with the catalyst from 1 of CO and 1 of H using iron, to 1 of CO to 2H using cobalt or nickel.

Fortunately, there are many sources of carbon and hydrogen and the process is flexible enough to be made suitable for carbons ranging from cannel coal to anthracite. The hydrogen may be a water gas, coal gas or electrolytic product. Thus, using coking coal, the coke ovens may be air blown and their resulting gas, admixed with steam, passed over glowing coke in

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* Presidential Address delivered at the Eighteenth Annual Corporate Meeting of the Institution of Chemical Engineers, held in London on Friday, April 5, 1940. Abridged.

a water-gas type of plant, when the hydrocarbons of the oven gas are decomposed into H and CO, and this contains the approximate proportion of 30 per cent. CO and 60 per cent. hydrogen. The gaseous reagents must be free, or substantially free, from sulphur, otherwise the catalyst "sickens," and this sulphur eradication has proved a very troublesome problem. But purification has arrived at a stage where, using cobalt thorium precipitated on kieselguhr as catalyst, a yield of 110 g. is produced per cubic metre of mixed gas with a degeneration of catalyst to 80 per cent. of its original activity after 60 days. These are very notable figures. Further, later research has shown that, by adjustment of pressures up to 150 lb. per square inch, the paraffin yield may be increased, and the above total yield exceeded by 25 per cent. The products are heavier bodies and have to be cracked or otherwise treated for marketing purposes.

At the end of 1937, there were six Fischer-Tropsch plants at work in Germany, and the cost per English gallon translated into sterling at 12·50 marks = 1*l.*, was 8½*d*. Eight more plants are being built or are being designed, and in one or two of these later plants, pressure catalysis has increased the yield. I am reasonably certain that this figure, to-day, is too low, and my request for an accountant's check did not meet with a response that indicated sincerity. Nevertheless, I believe that the figure will ultimately drop. The output in Germany to-day from her plants is 1,050,000 tons, most of which is suitable, after "doping," for internal-combustion engines. An average run is somewhat as follows :—

	Boiling point.	Per cent. in weight.
Light hydrocarbon ...	... Under 30 deg. C.	8
Petrol	... 30-200 deg. C.	50
Diesel oil	... Over 200 deg. C.	39
Soft paraffin wax, m.p.	... 50 deg. C.	3
		100

The process absorbs a great deal of coal. Hence, any plant for oil from coal, whether it be Fischer-Tropsch or any other, must be above, near, or have ample facilities for coal. It must also have it for many years to come. Transport will not, I venture to think, become cheaper—if it does, so much the better, but to have to load coal on to a truck from the pit, haul it out, and deliver it elsewhere, costs money out of all proportion to its initial cost of winning. So the problem again compels its own solution. Taking a young coal (*i.e.*, bituminous) as the starting stock, it would require 5½ tons of coal to obtain 1 ton of total oil product. Taking coal in relation to petrol, on the yield given above, 9 tons of coal are wanted per ton. Hence, for a 100,000 tons per annum synthetic-oil plant producing all grades, 550,000 tons of coal are required. If the plant is to stay in production over an economic cycle, say 40 years, it will require 22,000,000 tons of coal.

Do not think that the progress abroad has remained unnoted. The Fuel Research Department has kept track of development. Our oil companies have their own very accurate means of knowing all developments, and finally, there was the Falmouth Report of 1938. Would that this deliberation had taken place after September 3, 1939. Its summary is as follows :—"The Committee consider that it would be of considerable advantage if the establishment of a plant to work the Fischer process, and designed for the production of not less than 20,000 tons to 30,000 tons of primary products per annum could be secured. They hope that, with the extension of the guaranteed preference, one or more industrial concerns may be induced to undertake the erection of such a plant. But if financial assistance is requested from the Government, the Committee recommend that such assistance should be limited to sums required for special items of research work which, by agreement with the Department of Scientific and Industrial Research, can be recommended as being of national interest." So far, nothing has been done.

CONTROL OF CHROMIUM AND CHROMIUM COMPOUNDS.—The Ministry of Supply informs us that some misapprehension appears to exist as to the effect of Direction No. 1 of the Control of Chromium, Magnesite and Wolfram (No. 1) Order, 1940, on the schemes of distribution of bichromates and their derivatives which are at present operated by the Ministry. It is not the intention that the Order, with its formal requirements of licences, etc., should be applied to these materials which, thanks to the co-operation of manufacturers and consumers, have been successfully brought within the voluntary schemes; and, for this reason, the Direction No. 1, issued under the Order, altogether exempts them, for the time being, from the licensing arrangements. It is the desire of the Ministry that the voluntary schemes of control should remain in force; but it will be appreciated that their continuance is mainly dependent on the ready co-operation of all in the trades affected by them.

TENDERS.

WE have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are as stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Boiler Plant, comprising a vertical cross-tube boiler of the 100 lb. class, to evaporate 1,100 lb. of water per hour; and two vertical boiler-feed pumps, having an output of 270 gallons per hour, for Grahamstown Mental Hospital Laundry. Union Tender and Supplies Board, Pretoria; May 23. (T. 18,480/40.)

Telephone Rectifying Equipment, comprising 5 rectifiers—24 volt, 0·5 ampere; seven rectifiers—24 volt, 1 ampere; and six rectifiers—24 volt, 2 amperes. Posts, Telegraphs and Telephones Administration, Rabat, Morocco; May 20. (T. 18,659/40.)

Generator Sets, six, 5 kVA, 230-volt, 50-cycle, single-phase, Diesel-engine driven. Post and Telegraph Department, Wellington, N.Z.; May 27. (T. 18,693/40.)

Sewage-Pump Wagons, three, and 10 carts for the transport of sewage. Ministry of Public Health, Municipalities Department, Cairo, Egypt; May 27. (T. 18,686/40.)

Pole Fittings for the Post Office. Union Tender and Supplies Board, Pretoria; May 23. (T. 18,812/40.)

Laundry Machinery for Bloemfontein Mental Hospital, comprising a 38 in. by 30 in. linen-washing machine; a 42 in. by 84 in. washing machine; two 36 in. by 26 in. hydro-extractors; one 40-gallon soap and soda dissolver; five 15 in. by 120 in. four-roller ironing machines; a 12-ft. by 9-ft. continuous dryer; and four laundry wagons. Union Tender and Supplies Board, Pretoria; May 30. (T. 18,811/40.)

Telephone Apparatus, comprising magnet and P.B.X. switchboards, relay set, mounting plates and shelves. Union Tender and Supplies Board, Pretoria; May 23. (T. 18,813/40.)

Miscellaneous Articles, including hessian, needles, fuses, bath bricks, accessories for kerosene lamps, paints and varnishes, tools and ironmongery, pipes, steel, iron and other metals. Prisons Administration, Cairo, Egypt; June 5. (T. 18,559/40.)

Electrical Equipment, including hard-drawn copper insulated wire, house-service meters, electric lamps, lead-covered and armoured cables, steel tubular poles, eight 3,300-volt, three-phase, totally-enclosed switchgear units, and eight oil-immersed, self-cooled, transformers. Electricity Supply Department Pietermaritzburg, Natal; May 9. (T. 18,773/40.)

Storage-Battery Locomotive, for 2-ft. gauge and 30-lb. rails, and of a total weight of 6 short tons. Two motors preferred, of a total horse-power of 22 to 26. Union Tender and Supplies Board, Pretoria; May 16. (T. 18,974/40.)

Metering Apparatus for insertion in a 9-in. pipe line; capacity to be not less than 45,000 gallons per hour. Town Council of Springs, South Africa; May 22. (T.Y. 18,980/40.)

BOOKS RECEIVED.

American Machinists' Handbook and Dictionary of Shop Terms. A Reference Book of Machine-Shop and Drawing-Office Data, Methods and Definitions. By F. H. COLVIN and S. A. STANLEY. Seventh edition, revised and enlarged. London: McGraw-Hill Publishing Co., Ltd. [Price 26*s.*]

Brazing: Principles, Materials and Methods. Manchester: Emmott and Co., Ltd. [Price 1*s.* net.]

United States Geological Survey. Bulletin No. 898-E. *Spirit Leveling in Missouri.* Part 5. *Southwestern Missouri*, 1896-1937. By J. G. STAACK. [Price 20 cents.] Bulletin No. 890-A. *Spirit Leveling in South Carolina.* 1896-1938. By J. G. STAACK. [Price 55 cents.] Bulletin No. 905. *The Coal Resources of McCone County, Montana.* By J. A. COLLIER and M. M. KNECHTEL. [Price 75 cents.] Washington: Superintendent of Documents.

Hardening and Tempering Engineers' Tools. Including Notes on Forging, Case-hardening, and the Treatment of Special Steels. By GEORGE GENTRY. London: Percival Marshall and Co., Ltd. [Price 1*s.* 6*d.* net.]

United States National Bureau of Standards. Report BMS 34. *Performance Test of Floor Coverings for Use in Low-Cost Housing.* Part I. By P. A. SIGLER and E. A. KOERNER. [Price 10 cents.] Report BMS 36. *Structural Properties of Wood-Frame Wall, Partition, Floor and Roof Constructions with "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co.* By H. L. WHITTEMORE and A. H. STANG, with the collaboration of T. R. C. WILSON. [Price 10 cents.] Report BMS 41. *Effect of Heating and Cooling on the Permeability of Masonry Walls.* By C. C. FISHBURN and P. H. PETERSEN. [Price 10 cents.] Washington: Superintendent of Documents.

PERSONAL.

MR. S. J. C. ELLIS has been appointed city electrical engineer of Canterbury in succession to MR. F. E. LEWIS who died recently.

MR. N. C. BRIDGE has been elected chairman of the Scottish Branch of the Institution of Mechanical Engineers for the second year in succession.

SIR FELIX POLE has been elected president of the Electric Vehicle Association of Great Britain in succession to the late COLONEL R. E. B. CROMPTON.

MR. R. WILLIAMS, borough engineer and surveyor, Preston, has been appointed borough engineer and surveyor, Eastbourne, in place of MAJOR LESLIE ROSENARE, who is retiring.

MR. J. L. WILSON and MR. E. S. NEW have been elected chairman and vice-chairman, respectively, of the British Electrical and Allied Manufacturers Association.

MR. J. G. COFFEY, late Engineering Inspector of the Department of Local Government, Eire, has been appointed County Surveyor of Kilkenny.

DR. L. H. LAMPITT has been reappointed honorary treasurer and MR. J. DAVIDSON PRATT, honorary foreign secretary, of the Society of Chemical Industry.

MR. G. V. SPARROW is retiring from the position of waterworks engineer, Poole, Dorset, at the end of this month.

MR. R. C. MILLER has been appointed to succeed the late MR. H. WAUCHOPE as electrical engineer of the Docks and Marine Department of the Southern Railway Company.

The Minister of Supply has appointed LORD CATTO to be Director General of Equipment and Stores in succession to LORD WOOLTON, who was recently appointed Minister of Food.

MR. E. J. H. LEMON, who is a vice-president of the London Midland and Scottish Railway, was "lent" to the Air Ministry two years ago to organise the production department and to carry out a particular programme of production. This important work having now been successfully accomplished, he has been released by the Air Ministry and is returning to the Railway Company. He will, however, remain a member of the Supply Committee.

LORD ASHFIELD has been reappointed Chairman of the London Passenger Transport Board for a further period of seven years from May 18, 1940.

MAJOR R. FALSHAW MORKILL and MR. R. DELL have been appointed joint signal engineers of the London Passenger Transport Board, in succession to the late MR. W. S. EVERY.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—New business remained difficult to negotiate on the Welsh steam-coal market last week, but both home and overseas customers were displaying a close attention and a brisk demand was circulating. Almost the whole of the collieries' present outputs were earmarked for deliveries being made on account of existing contracts and order books were usually sufficiently well filled to ensure the maintenance of present conditions for a long time to come. The general tone was consequently very firmly maintained. The steps being taken to augment the district's output of coal to enable exporters to take fuller advantage of the increased demand were again attracting a good deal of attention. Duff coals continued to provide the outstanding feature of the market. Supplies for shipment over several months ahead were not plentiful, and a strong tone ruled. Sized and large qualities were well provided with forward outlets, while smalls were again only very sparingly offered. Cokes were in request, but were scarce. Patent fuel remained busy.

The Iron and Steel Trade.—Active conditions ruled in the iron and steel and allied trades of South Wales and Monmouthshire throughout the past week. The demand was sustained and works were kept almost fully occupied in fulfilling orders already on their books.

HOME-PRODUCED FUELS FOR INTERNAL-COMBUSTION ENGINES.—The committee appointed in March by the Secretary for Mines, to consider the best means of encouraging and developing the use of home-produced fuels in internal-combustion engines, are now preparing their report. Before completing it, however, they wish to be satisfied that all interested individuals or organisations have an opportunity to submit their views. They are prepared to consider any further correspondence or evidence, provided that it is forwarded not later than May 10. Communications should be addressed to the Joint Secretaries, Committee on Home-Produced Fuels for Internal-Combustion Engines, Metropole Buildings, Northumberland-avenue, London, W.C.2.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The increased use of concrete in all types of constructional work has had a beneficial effect on the demand for grinding and crushing machines, and for sand and gravel washing plant; outputs of jaw crushers and granulators reach record dimensions. Another progressive section is that devoted to the production of coal-mining equipment. All types of pumps are in demand, in addition to coal-cutting machines, steel tubs, and haulage gear. The call for steelworks and ironworks machinery and related equipment is well up to recent level. Every effort is being made to increase the output of all types of special steels, such as stainless, heat- and acid-resisting, and material capable of withstanding excessive strain and wear. Manganese steel is in demand for the manufacture of railway and tramway points and crossings, and the wearing parts of heavy machinery. The raw and semi-finished steel branches are operating at high pressure, and are producing record outputs.

South Yorkshire Coal Trade.—The export position is not very promising, but the inland market is very active; there is a record demand for industrial coal, and steams are particularly active. Locomotive coal is being ordered in larger quantities, and smalls and slacks also find a ready market. House coal sales are satisfactory. Cokes are in demand, particularly foundry and blast-furnace varieties.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Maximum production is still general in the Scottish steel trade, and the large output is rapidly taken up. The demand is increasing steadily and steel makers are endeavouring to fulfil all urgent orders. The raw material position can be reported as satisfactory because of the increased quantity of steel scrap which has lately been arriving. Specifications for structural sections amount to a considerable tonnage. Black and galvanised sheets are also in great demand and the mills are kept running to capacity. The export trade is good and every endeavour is being made to meet the overseas demand as fully as possible. Prices are steady and are as follows:—Boiler plates, 13*l.* 8*s.* per ton; ship plates, 12*l.* 10*s.* 6*d.* per ton; sections, 12*l.* 8*s.* per ton; medium plates, under $\frac{3}{16}$ in. thick, weighing 6 lb. or more per square foot, 14*l.* per ton, and weighing under 6 lb. but not less than 4·81 lb. per square foot, 14*l.* 10*s.* per ton; black-steel sheets, No. 24 gauge, in 4-ton lots, 17*l.* 10*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, in 4-ton lots, 20*l.* per ton, all delivered at Glasgow stations.

Malleable-Iron Trade.—The recent improvement in the supply of raw materials has enabled the West of Scotland malleable-iron makers to keep their plant running fully as the demand is very steady. The re-rollers of steel bars report that a similar state prevails and that the pressure for deliveries continues. Supplies of semi-manufactured steel from overseas have been very satisfactory of late. The current quotations are as follows:—Crown bars, 14*l.* 2*s.* 6*d.* per ton; No. 3 bars, 12*l.* 10*s.* per ton; No. 4 bars, 12*l.* 15*s.* per ton; and re-rolled steel bars (tested), in 4-ton lots, 14*l.* 3*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—There has been no change in the state of the Scottish pig-iron trade during the week and the demand is as pressing as ever. The furnaces in blast are operating to capacity and no time is lost in sending out the full production. The following are to-day's market prices:—Hematite, 6*l.* 7*s.* 6*d.* per ton, and basic iron, 5*l.* 4*s.* 6*d.* per ton, both delivered at the steelworks; foundry iron, No. 1, 5*l.* 15*s.* per ton, and No. 3, 5*l.* 12*s.* 6*d.* per ton, both on trucks at makers' yards.

THE ASSOCIATION OF TEACHERS IN TECHNICAL INSTITUTIONS.—The 31st annual conference of the Association of Teachers in Technical Institutions is to be held at the Hotel Russell, Russell-square, London, W.C.1, on Sunday, May 12. Meetings of the Executive and Finance Committees, and of the Council, will be held on the previous day. The conference will be opened on May 12, at 10.0 a.m., when the President, Dr. E. A. Seeley, will take the chair, and will induct the President for 1940-41, Mr. S. H. Moorfield, who will then deliver his presidential address. Resolutions to be put to the meeting will deal with current problems of evacuation, junior technical schools, education for world citizenship, and the harmful effects of excessive overtime upon students. The meeting will be followed by a luncheon, and at 2.0 p.m. will be opened the annual general meeting of the Association, attendance at which is restricted to members. After an interval for tea, the Council for 1940-41 will hold its first meeting. Further particulars may be obtained from the secretary, Mr. A. E. Evans, at the offices of the Institution 29, Gordon-square, London, W.C.1.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—Conditions in the iron and allied trades still confine general commercial business to narrow limits. The usual buyers, of nearly all commodities, have substantial orders to place, both for home purposes and for shipment abroad, but little tonnage is available for ordinary industrial requirements.

Cleveland Iron Trade.—While there is no actual shortage of foundry iron, saleable parcels are few and small. Deliveries of Midland iron continue to arrive with satisfactory regularity and supplies from that quarter promise to be maintained. Second-hands have control of only moderate lots of local iron or of products from elsewhere. The prospects of a resumption of the regular make of Cleveland pig are still remote. Fixed prices remain on the basis of No. 3 description at 111*s.*, delivered within the Tees-side zone.

Hematite.—The heavy output of East Coast hematite is well maintained and may be increased, but the statistical position enforces precedence and producers are unwilling to sell at all extensively, until they have reduced their delivery obligations. The heavy and increasing needs of producers' own consuming works are absorbing the bulk of the supply and the requirements of users who have to make market purchases are taxing the resources of makers. The latter, however, are confident of their ability to deal with actual requirements for consumption. Stabilised values remain at the equivalent of No. 1 grade of hematite at 127*s.* 6*d.*, delivered to North of England areas.

Basic Iron.—The whole of the output of basic iron continues to pass promptly into direct use at makers' adjoining steelworks and the quotation of 104*s.* 6*d.* is nominal.

Foreign Ore.—Consumers of foreign ore have satisfactory stocks and are expecting to receive adequate supplies.

Blast-Furnace Coke.—Buyers and sellers of Durham blast-furnace coke have little need to negotiate. The former are well covered and the latter are not anxious to add materially to their extensive commitments. The recognised market values are ruled by good medium qualities at 31*s.* 8*d.* at the ovens.

Manufactured Iron and Steel.—The substantial make of semi-finished iron and steel, supplemented by a considerable import of Continental semics, enable deliveries to be made to re-rollers on a scale that keeps the mills busily employed. In the finished industries, producers of light and heavy materials, have programmes to carry out that ensure the fullest use of plant for some months ahead. The outputs of all classes of steel are maintained at record levels and manufacturers have an accumulation of orders to be carried out. The control of distribution, however, promises to facilitate matters.

Scrap.—There is some further improvement in the supply of iron and steel scrap.

ROYAL AERONAUTICAL SOCIETY.—The next associate-fellowship examinations of the Royal Aeronautical Society will be held on May 22 and 23. Full particulars are to be sent direct to candidates who have entered for the examination.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—At the closing general meeting of the session, held on April 19, Mr. W. A. Woodeson was elected President of the North-East Coast Institution of Engineers and Shipbuilders, in succession to Major T. Russell Cairns. The latter announced during the meeting that the Council, through its Reading Committee, had well in hand preparations for an active 1940-41 session. A number of important papers were promised.

ELECTRICALLY-HEATED SWIMMING POOL AT BUCKINGHAM PALACE.—A portion of Buckingham Palace has recently been rearranged to accommodate a swimming bath, with a squash court at one end, and dressing rooms, showers, Turkish and Russian baths, at one side, the whole occupying a very small space. The engineering equipment is installed in the basement and consists essentially of an electrode boiler constructed by Messrs. Bastian and Allen, Limited, 24, Bedford-square, London, W.C.1. This boiler, which is fitted with automatic time and temperature controls, delivers hot water to the main storage cylinder, from which, in turn, supplies are drawn for heating the building and the swimming bath. A separate cylinder with immersion heaters provides hot water for the showers. Owing to the small space available, the Turkish bath consists of one instead of several rooms, the temperature being rapidly raised by means of a plenum system, which is controlled by the operation of one handle. The Russian bath is supplied with steam from a small automatic boiler behind which is the duct from the electric air heater for the Turkish bath.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

IRON AND STEEL INSTITUTE.—To-day, 4, Grosvenor-gardens, Westminster, S.W.1. Continuation of the Seventieth Annual General Meeting. 10 a.m., presentation of various papers. 1 p.m., Grosvenor House, Park-lane, W.1. Members' Luncheon. For programme, see page 366 *ante*.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Meter and Instrument Section:* To-night, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Lecture: "Insulation," by Mr. H. Warren. *Transmission Section:* Wednesday, May 8, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. "Mechanical Integrity in the Design of Electrical Circuit-Breakers," by Mr. M. C. Hunter. *Institution:* Thursday, May 9, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Annual General Meeting. (For Corporate Members and Associates only.)

INSTITUTION OF MECHANICAL ENGINEERS.—*Internal Combustion Engine Group:* To-night, 6.30 p.m., Storey's-gate, St. James's Park, S.W.1. Informal Discussion: "Operating Experience with Gas Producers."

ROYAL INSTITUTION.—Monday, May 6, 5 p.m., 21, Albemarle-street, W.1. General Meeting.

INSTITUTION OF CHEMICAL ENGINEERS.—Tuesday, May 7, 5.15 p.m., The Geological Society's Rooms, Burlington House, Piccadilly, W.1. Ordinary Meeting. "Measurement of the Flow of Liquids and Gases," by Mr. E. Ower.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, May 7, 5.30 p.m., Great George-street, Westminster, S.W.1. "Cliff Stabilisation Works in London Clay," by Mr. J. Duvivier.

ROLLED ZINC IN THE UNITED STATES.—The output of rolled-zinc sheet, plate and strip in the United States, in 1939, totalled 61,882 short tons, against 45,875 tons in 1938.

REUNION OF PAST AND PRESENT CREWE APPRENTICES.—The 50th annual dinner of past and present Crewe pupils and premium apprentices will be held at Oddenino's Hotel, 54, Regent-street, London, W.1, when the Chair will be occupied by Sir Nigel Gresley, C.B.E. The honorary secretary of the function is Mr. Reginald Terrell, 3, Victoria-street, London, S.W.1, who informs us that he would like to hear from past Crewe men who would care to attend.

ORDERS FOR TROLLEY-'BUS EQUIPMENT.—Among contracts for electrical equipment for trolley omnibuses received recently by Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, are orders from Cardiff, Edmonton, Canada, and Hobart, Tasmania. The ten equipments in hand for Cardiff are of particular interest as they represent the first stage in the change-over from tramways to trolley omnibuses in that city. Both contracts represent repeat orders, the Canadian contract including three equipments similar to those supplied towards the end of last year, and that for Tasmania constituting a fifth repeat order.

TECHNICAL BRANCH, ROYAL AIR FORCE VOLUNTEER RESERVE.—The Air Ministry informs us that the Royal Air Force requires a number of technical officers for employment on engineering, armament, and signals duties. Commissions in the newly-formed Technical Branch of the Royal Air Force Volunteer Reserve will be granted for the duration of hostilities to suitable applicants between the ages of 21 and 50. Candidates should be holders of engineering degrees, and, for engineer or armament duties, should be practical engineers who have served an apprenticeship followed by a number of years' practical experience. For signals duties, applicants should be holders of engineering or science degrees, holders of technical-college or approved-institute diplomas, and have two years' experience in telecommunication engineering, preferably on the radio side. Candidates, whose qualifications do not reach the high standard required of officers of the Technical Branch, but whose services can be utilised on special duties of a technical character—may be offered commissions in the Administrative and Special Duties Branch of the R.A.F. Volunteer Reserve. Candidates should apply at once, in writing, to the Air Ministry, S.7.e.5., Adastral House, Kingsway, London, W.C.2, giving full particulars of their qualifications, training and experience. Personal calls and telephone inquiries should be avoided. Candidates who are engaged on the production of aircraft, engines or accessories, or on other important national work, should not submit applications without first consulting their employers as to the possibility of their being spared for R.A.F. duty.

THE CHILCOTE PUMPING STATION OF THE SOUTH STAFFORDSHIRE WATERWORKS COMPANY.

MR. FRED. J. DIXON, M.INST.C.E., M.I.MECH.E., ENGINEER-IN-CHIEF.

(*For Description, see Page* 451.)

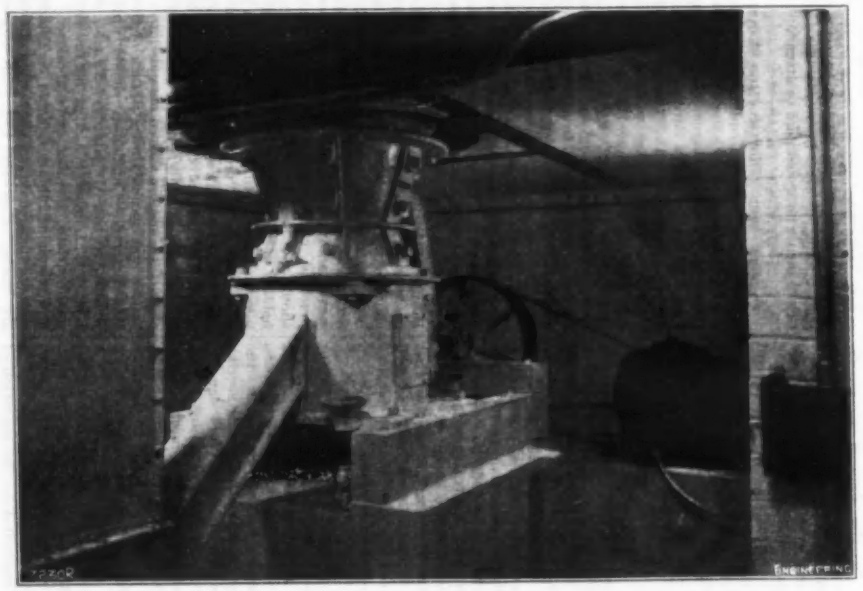


FIG. 16. STURTEVANT ROTARY CRUSHER.

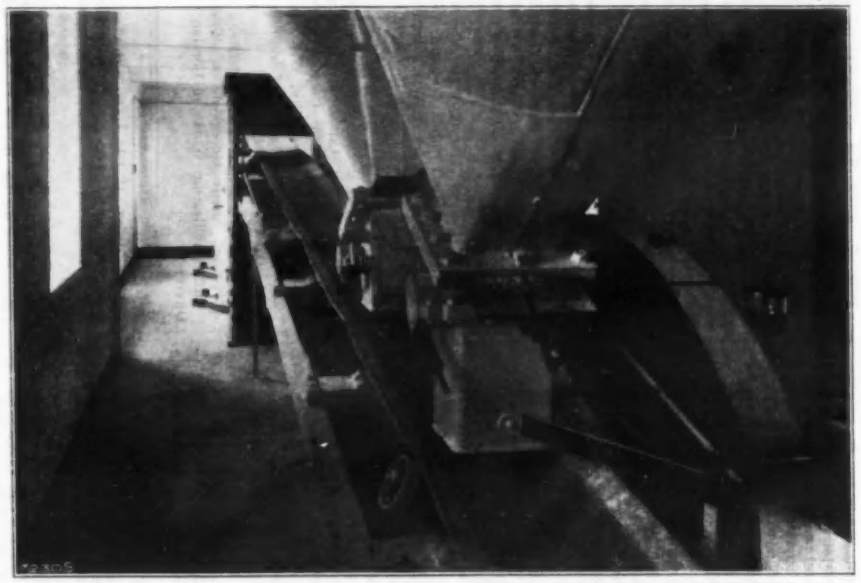


FIG. 17. OUTLETS FROM LIME BINS AND CONVEYOR BELT.

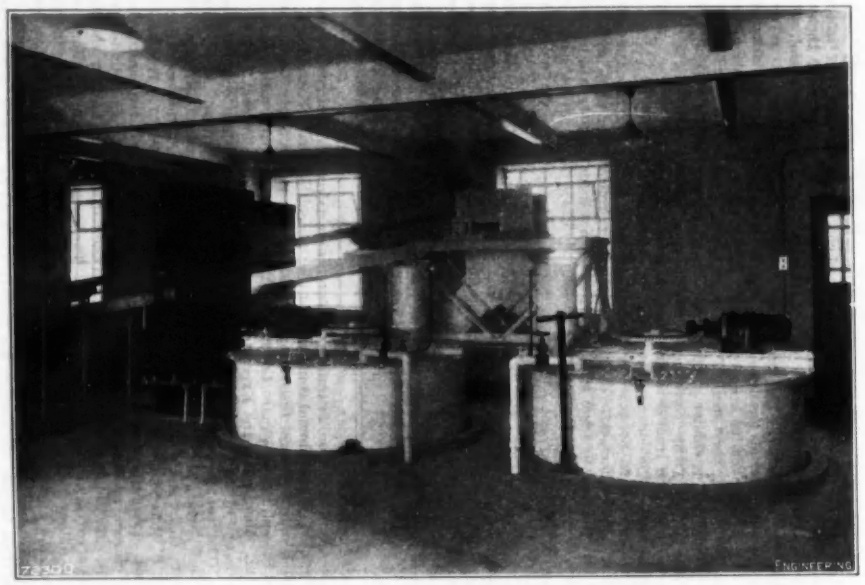


FIG. 18. LIME SLAKERS AND CONTINUOUS WEIGHER.

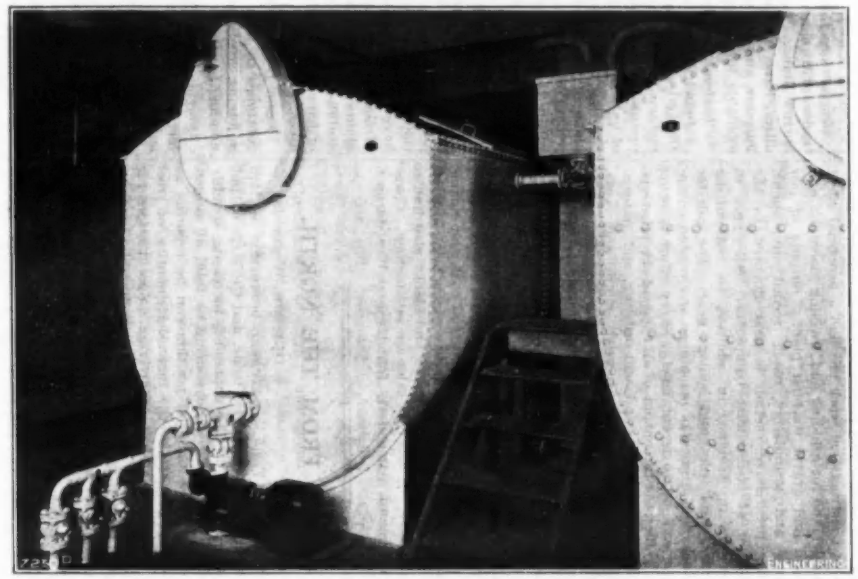


FIG. 19. CREAM OF LIME CONTAINERS AND PUMP.

THE CHILCOTE PUMPING STATION OF THE SOUTH STAFFORDSHIRE WATERWORKS COMPANY.

MR. FRED. J. DIXON, M.INST.C.E., M.I.MECH.E., ENGINEER-IN-CHIEF.

(*For Description, see Page* 451)

Fig. 6.

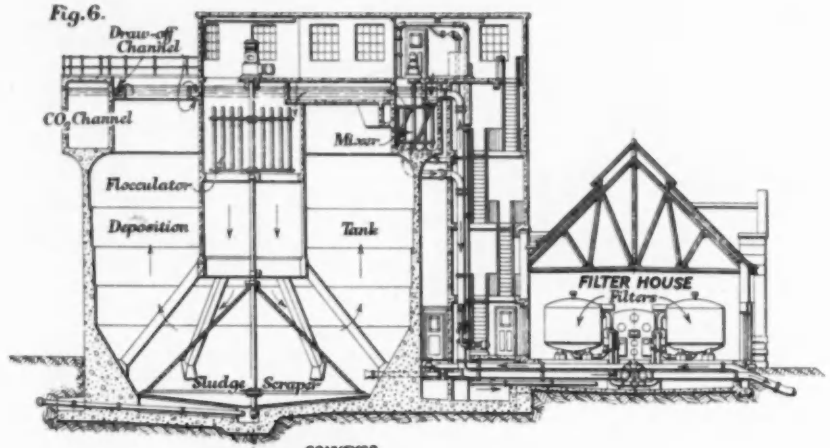


Fig. 7.

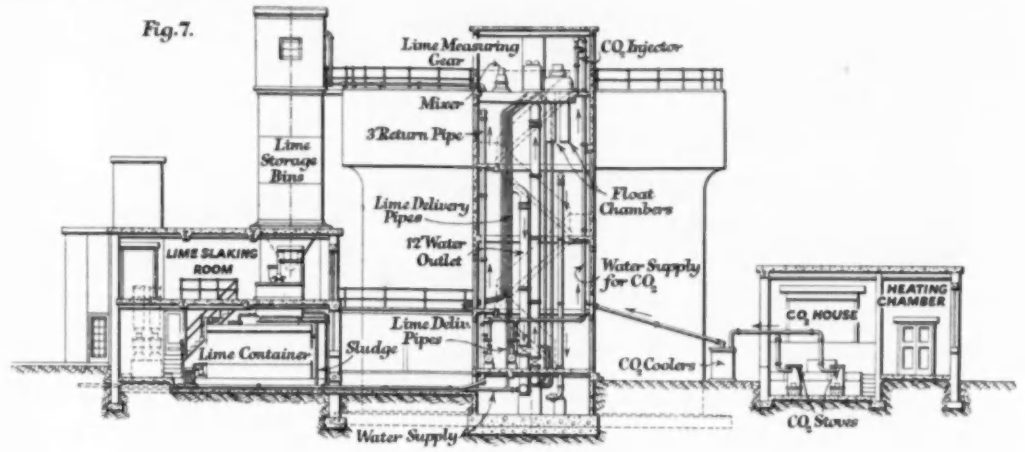
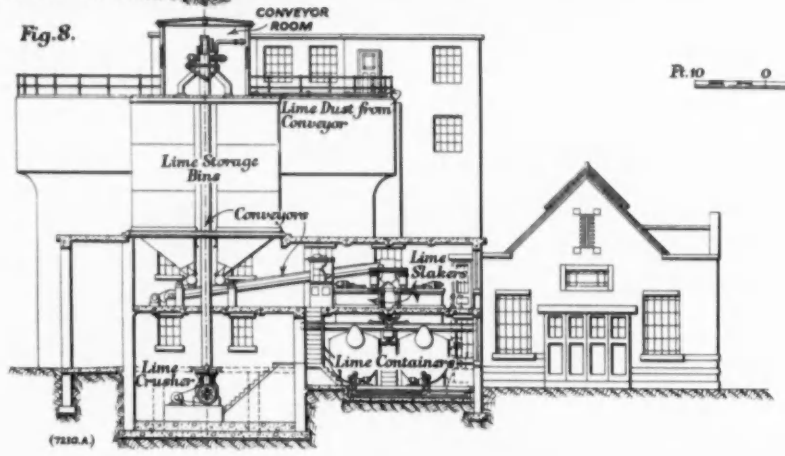
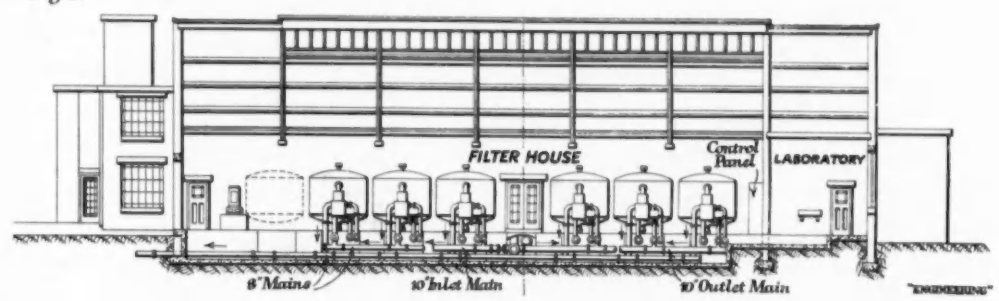


Fig. 8.



Ft. 10 0 10 20 30 40 Feet

Fig. 9.



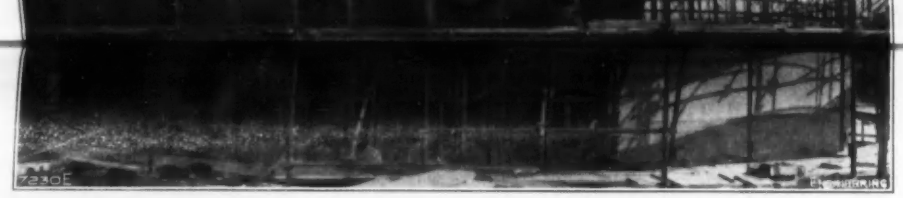


Fig. 10. Deposition Tank in Course of Construction.

Fig. 11. CO_2 House in Front of Deposition Tank.

Fig. 12. Construction of Wall of Deposition Tank.

Fig. 13. Water Flowing from Deposition Tank into Collecting Channels.

Fig. 14. Central Scraper in Deposition Tank.

Fig. 15. Deposition Tank, Lime Bins and Lime-Storage House.

ENGINEERING.

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ENGINEERING

FRIDAY, MAY 3, 1940.

VOL. 149. No. 3877.

ACCEPTANCE TESTS FOR MACHINE TOOLS.

THE introduction of standard specifications for machine tool tests and alignments has been discussed at intervals in this country over a number of years, and in 1933 a British Standards Committee was set up to prepare such specifications. The work of this committee received no support from the representative organisation of the machine tool manufacturers, and it was presumably disbanded. In some other countries more progress has been made and the first edition of Dr. Schlesinger's charts for tests and alignments was published in Germany in 1927. A French edition of this work appeared in 1929. This improved on the original by emphasising the distinction between the two types of test concerned —those relating to the accuracy of the machine and those relating to the accuracy of the work turned out by it. These were termed respectively geometric tests and practical tests. In 1933, Lieut.-Colonel P. Salmon, Head Inspector for the purchase of machine tools by the French Government, expressed the view that it was necessary to stipulate the conditions under which practical tests should take place and that only in exceptional cases was it necessary to insist on tests and alignments of the tools themselves. The respective claims of the Schlesinger geometric system and the Salmon practical system have been discussed by a committee of the International Federation of National Standards Associations over a number of years. No general agreement has been reached, though this has not prevented the extensive use of the Schlesinger system in Germany.

Despite this lively interest on the Continent, little progress has been made in this country. The question of such tests has been raised occasionally at meetings of the Institution of Mechanical Engineers and in January, 1938, Dr. Schlesinger presented a paper dealing with the subject. The discussion following the reading of that paper suggested that there was a considerable body of opinion which was inclined to favour the adoption of some type of standard. Replying, Dr. Schlesinger stated that the manuscript of his original publication on the subject was submitted to the Standards Committee of the German Machine Tool Makers' Association in 1910. Little attention was, however, paid to it until the specification of allowable tolerances introduced by the Russian Government, in connection with large orders for machine tools, led to the rejection of large numbers of German tools. The controversy was settled by the appointment of Dr. Schlesinger as arbitrator with authority to prescribe final acceptance tests; and he quoted this incident to emphasise the value of generally accepted tests in the development of export trade.

Dr. Schlesinger is now Director of Research for the Institution of Production Engineers. When a few years ago the provision of funds and necessary facilities enabled that Institution to enter the field of research, one of its first acts was to appoint Dr. Schlesinger to his present post, and it is a matter for no surprise that one of the first objectives of its Research Committee has been the formulation of proposals for acceptance tests for machine tools. Apart from the importance of the subject itself, it was natural that advantage should be taken of the special and authoritative position which Dr. Schlesinger occupies in this field. The result has been the publication of *Acceptance Test Charts for Machine Tools* jointly by the Institution of Mechanical Engineers and the Institution of Production Engineers. The document has been prepared by the Research Department of the latter Institution and the fact that the former has associated itself so prominently with it may be taken as evidence that its Council is of opinion that the time is now ripe for the introduction of British standards in this important field. This, indeed, is made clear by the closing works of the introduction to the charts, "It is hoped that the great amount of detailed work which has been carried out in producing these charts will materially assist in their acceptance as a standard, and so end the controversy which has been carried on for so many years."

It is pointed out in this introductory section, which gives an interesting historical survey of the subject, that "the charts are not intended for the practical use of the builder of machine tools except for the purpose of giving him a guide and a standard for reference in cases of dispute." The point of view which this sentence expresses is clearly inherent in the genesis of the charts. The Institution of Production Engineers, which is responsible for them, is essentially an association of users, whose interests lie in the accuracy of the work turned out rather than in the detailed accuracy of the machines themselves. This disclaimer, however, has not prevented the Machine Tool Trades Association from receiving the report in the terms expressed in the letter printed on page 468, advising members not to accept orders conditioned on conformity with the charts. As members of the Association can now get many more orders than they can possibly execute, and as any disputes about these or any other charts, which would be likely to hold up production, would be dealt with by a higher authority than either the Machine Tool Trades Association or the Institution of Production Engineers, the point is of no practical interest.

The Association would certainly appear to have some justification for the contention in the first paragraph that the energies of machine-tool builders cannot now be spared for the discussion of new standards. It is a fair assumption that the main reason why the charts have appeared now is that the Institution of Production Engineers has, for the first time, found itself in a position to compile them. They, and the Institution of Mechanical Engineers, can hardly have imagined that they would or could be extensively adopted in present conditions. As the Association's letter implies, discussions more recent than those of 1933, to which we have already referred, have taken place with the British Standards Institution on this subject. The statement that

the Institution "did not regard it as practicable at the present time to proceed with the question" may be taken to mean that it was not prepared to proceed without the collaboration of the makers. This is not surprising; such a proceeding would be entirely outside its usual methods and practice. As, however, not all British machine-tool makers are opposed on principle to the introduction of such standards, it is possible that this subject may be included eventually in its activities.

Although it may appear that the tackling of this question has been long delayed in this country, the Machine Tool Trades Association have every justification for refusing to be hurried into premature decisions. As pointed out in the introduction to the charts, the International Federation of National Standards Association discussed this subject at Budapest and Berlin in 1936; at Paris in 1937; at Stockholm in 1938; and at Rome and Helsinki in 1939. As no agreement has been come to at these six meetings, spread over four years, it does not appear unreasonable that the Machine Tool Trades Association should refuse to commit itself on the subject under present conditions.

Although the new charts can have no compulsory or even official status, they are likely to be received with attention and studied with care because of the authoritative bodies by which they have been put forward, and it would not be stretching probability too far to suggest that they may some day form the basis of British standards. The present publication covers centre lathes, various types of milling machines, external grinding machines, and radial drilling machines, but further charts are to follow in due course. That there is still a large field to be covered will be made very clear by a comparison of the present publication with the second edition of Dr. Schlesinger's *Prüfbuch für Werkzeugmaschinen*, which deals with 37 types of machine, including, for instance, presses and shearing machines, as well as the wide range of tools now to be found in the machine-shop proper. The charts in the Production Engineers' publication are in the form of folding plates which can be purchased separated, at 6*d*. each. The price of the complete publication is 5*s*. 6*d*. The diagrams are larger than those in the German publication, but are not clearer. The paper is heavy, but it is doubtful if it will, in constant use, have as good a life as the harder paper used for the German charts. These latter also have a decided advantage in the method of binding adopted. The brochure will open flat, and stay open at any page, and has a flexible leather cover with a vertical joint down the centre which permits it to be doubled up for carrying in the pocket. In these respects, it compares favourably with the somewhat cumbersome British publication, which requires a fairly heavy weight on the left-hand page to keep it open, and has only a paper cover.

FOOD RESEARCH.

THE scientific approach to the problems of the preparation, transport and storage of foodstuffs, always of importance to a predominantly industrial country, has become a primary necessity to this nation, at war and supporting large bodies of troops overseas. Very appositely, therefore, comes the publication of the latest annual report of the Food Investigation Board.* The report, which has been delayed by the outbreak of war, actually relates to the work carried out during 1938; but, although it thus bears only indirectly upon the national economy under war conditions, it furnishes abundant internal evidence that the present emergency is likely to demand rather an intensification than a drastic alteration of the major research programmes, and that the scientific staff directed by the Board are fully competent to deal with the urgent food problems that have arisen during the past six months. These valuable qualifications are due, in no small measure, to the far-sighted policy of the Board, whereby investigations upon meat, fish, fruit and vegetables, as well as studies of the physical and engineering aspects of refrigeration and food preservation, have been conducted simultaneously for a number of years, in three associated research stations at Cambridge, Aberdeen and East Malling. This excellent organisation has been extended recently by the establishment of laboratories adjacent to the Smithfield and Covent Garden markets, equipped for chemical, physical and biological work, and intended to provide experimental facilities for the trade.

More specifically associated with the scientific aspects of the country's war-time food supply is an informal conference, under the Chairman of the Board, which was set up some two years ago at the request of the Food (Defence Plans) Department, and which has since been increasingly active in collecting and supplying technical information obtained, in part, from special investigations undertaken by the Low Temperature Research Station at Cambridge. Not unassociated, perhaps, with the existence of this conference, and certainly significant of the importance with which food investigation is regarded by the Defence Departments, is a notable expansion of the work of the Board to cover research upon the processing of food. Hitherto, except for limited studies of bacon manufacture, fish curing and fruit canning, the Board's resources have been concentrated upon the preservation of unprocessed food in fresh condition during transport and storage. Now that the handling of fresh food can be regarded as firmly established on a scientific basis, and fundamental knowledge of the properties and behaviour of raw foodstuffs has been accumulated over the whole range of the national dietary, the Board rightly consider that, in the interest of consumer, producer and manufacturer, their activities can be most usefully extended towards processing research. They take the view that, since the fundamental factor is the material rather than the process, their new research programme should be organised on that basis, and they are accordingly pressing forward with investigations into the physiology of animals and plants used for food, the behaviour and control of micro-organisms, and the biochemistry and biophysics of foodstuff constituents. While it may be difficult to improve upon the traditional methods of curing and preserving over a limited range of products, any attempt to increase the variety of processed foods will be substantially aided by the fundamental work now initiated by the Board.

As exemplifying, in a comparable direction, the importance of scientific investigation in improving the flavour and nutritive value of imported food, reference may be made to chilled beef, the first commercial consignment of which reached this country from New Zealand as recently as 1933. In this process the meat, as a result of the Board's work, is transported in gas-storage, that is, in air enriched to a controlled extent with carbon dioxide, and at temperatures considerably above those essential for the lengthy conveyance of frozen meat. The improvement in quality and the diminution of cooking shrinkage are such that chilled beef, prior to the war, commanded a premium in British markets of about a penny per pound over frozen beef, representing an increased value approaching 500,000*l*. for the annual imports into this country. Under the Board's direction, the extension of gas storage to the preservation of other fresh foods is being rapidly developed, and already successful experiments have been concluded upon fruit, vegetables and eggs. In the case of apples, a striking demonstration was made during the winter of 1937-38, when 26 tons of Cox's Orange Pippins were stored for five months at a temperature of 39 deg. F. in an atmosphere composed of 2·5 per cent. oxygen, 5 per cent. carbon dioxide, and 92·5 per cent. nitrogen. In the opinion of expert fruit growers, the stored fruit was in excellent condition, and it was established that the gas treatment had in no wise prevented the characteristic flavour of the fruit from being developed. Successful storage on this scale has not been achieved without encountering difficulties, one of which is noteworthy because it applies to ordinary cold storage as well as to gas storage. In general terms, it amounts to an interaction, which may have deleterious effects, between fruit in different stages of ripeness, stored together. Early ripe varieties of apples, for instance, exude volatile substances which cause lenticel spotting on late varieties stored in the same atmosphere. The development of mould upon the curds of broccoli is found, somewhat similarly, to be retarded by trimming the leaves before the vegetables are stored. It is encouraging that precautionary measures are being developed to ensure the successful applications of gas, not only to the storage of vegetable and animal foods, but also to the artificial ripening of fruit.

The Board's investigations of fish, among which the quality, preparation and storage of cured herrings have been predominant problems, are an excellent illustration of work already in progress upon an important type of food processing, and of some of the factors that have influenced the decision to organise process research on the basis of the raw material to be treated. Studies of herring, with special reference to feeding habits and their physiological effects, have revealed a marked and abrupt increase in the fat content of these fish during the month of June. Herring caught in this condition, however, are soft and easily torn during the curing operations, and the newly-acquired fat runs away readily in the smoking kiln. In herring caught a month later, however, the fat has consolidated and is largely retained in curing so that palatable kippers of firm marketable quality can be made. Chemical analysis of wood smoke, to ascertain the best possible procedure for smoking fish, has been carried out by the Chemical Research Laboratory at Teddington, but it is evident that, even were the process to be standardised, variations in the age, feeding and condition of the herring as caught would make it impossible to avoid a wide range of quality in the kippers. Here, as perhaps with most other cured foods, the effects of the process upon the eventual product are more easily determined than those of the raw material.

From the selected examples to which reference has been made, it may be inferred that the food investigations in progress are not only fundamental in all necessary directions but embrace every important type of perishable food, serving impartially the interests of consumer and producer. Incidental to all such work, yet essential to its practical utility and commercial success, is a considerable volume of physical and engineering research concerned with such matters as refrigeration, thermal insulation, ventilation, thermostatic control and the physical properties of foodstuffs under storage conditions. Many of the major problems in these directions, of course, have been satisfactorily solved so long ago that the Food Investigation Board has had no occasion to do more than make an improvement of detail here and there. To all the more recent developments of refrigerating and cold-storage practice, however, the Board has made, and continues to make, substantial contributions. Especially noteworthy, under this head, are their experiments concerned with air circulation and the associated evaporation of moisture from foods stored at low temperatures. It is the general practice to reverse, at regular intervals, the direction of the air circulation through refrigerated spaces, and serious loss of efficiency is commonly encountered when an axial-flow fan is reversed to achieve this object. By using blades of elliptical, instead of the conventional aerofoil, cross section, the staff at Ditton Laboratory have been able to design a fan which works at uniform and reasonably high efficiency in either direction of rotation. Studies of the aerodynamic resistance offered by stacked boxes exposed to ventilating currents in food stores have also figured prominently among the engineering work of the past two years, while problems of evaporation from moist surfaces, and of the effects of different types of food packings and wrapping materials, are examples of physical research that is of obvious value to the industry. In this class of work, the close collaboration among the various laboratories, not only of the Food Investigation Board, but of the whole Department of Scientific and Industrial Research, is an important factor at any time. Under emergency conditions, its potential value is enormously enhanced and can be extended, with the co-operation of the engineering profession, in many new directions.

* *Report of the Food Investigation Board for the Year 1938.* London: H.M. Stationery Office. [Price 4*s*. 6*d*. net.]

NOTES.

NEW POWER STATION FOR TURKEY.

A CONTRACT of considerable importance to British engineering prestige in Eastern Europe, as well as to the expansion of export trade, has been signed between representatives of the Turkish Government and Messrs. Metropolitan-Vickers Electrical Company, Limited, in connection with the electrification of the Turkish coal industry in Anatolia. The order is valued at approximately 1,500,000*l.*, and has been secured in the face of keen international competition. It includes the construction and equipment of a power station, with a capacity of 60,000 kW, at Catalagzi, on the shore of the Black Sea. This site has been selected by reason of its proximity to the Zonguldak coal basin, whence the station's fuel supply will be obtained. An overhead transmission line, about 16 km. (10 miles) in length, with three substations and the necessary switchgear, is also comprised in the contract. Provision will be made for possible future extensions. The initial generating plant is to consist of three 20,000-kW turbo-alternator sets, to run at 3,000 r.p.m., with central-flow condensers and a four-stage feed-heating system. Make-up feed water will be supplied by low-pressure evaporators. The condenser cooling water will be taken from the sea, the circulating pumps being arranged in a separate pump house on the shore. The main alternators will generate current at 11,000 volts, and each set will include a 1,500-kW alternator for house service. For stand-by purposes there will be a 375-kW auxiliary set, driven by a Diesel engine. The output from the main alternators will be stepped up to 66,000 volts by an outdoor transformer and switching station, controlled from within the power station. The main transformers will be 25,000-kVA three-phase units. For the equipment of the substations there will be provided nine 6,400-kVA outdoor transformers, stepping the current down to the 15-kV pressure for which the indoor switchgear is being designed. As sub-contractors to Messrs. Metropolitan-Vickers Electrical Company, Messrs. Babcock and Wilcox, Limited, will supply the boilers and the coal-handling plant; Messrs. Holloway Brothers (London), Limited, will undertake the civil-engineering work, including the construction of the buildings and the cooling-water intake; and Messrs. British Insulated Cables, Limited, are to supply the overhead transmission line and cable.

LUNCHEON TO THE UNITED STATES AMBASSADOR.

The outbreak of the war, in September last, occurred, it will be recalled, just as a joint party of members of the Institution of Civil Engineers and the Institution of Mechanical Engineers was on the point of departing for New York, where they were to hold a combined Engineering Congress with the American Society of Civil Engineers and the American Society of Mechanical Engineers. The projected visit was "postponed" at once; but the mere intention has served to bring the British and the American societies into a closer bond of mutual understanding, and there is little doubt that the programme will be revived at the first opportunity. A part of it, at least, has been accomplished. On Thursday, April 25, the Councils of the Institutions of Civil and Mechanical Engineers entertained His Excellency the United States Ambassador, the Hon. Joseph P. Kennedy, to luncheon at Grosvenor House, Park-lane; when he presented to Mr. W. J. E. Binnie, immediate past-president of the Institution of Civil Engineers, the diploma of honorary membership of the American Society of Civil Engineers, and to Mr. E. Bruce Ball, immediate past-president of the Institution of Mechanical Engineers, that of honorary membership of the American Society of Mechanical Engineers. But for the war, these marks of distinction would have been conferred in New York, in the course of the Congress and during the presidencies of Mr. Binnie and Mr. Bruce Ball. Sir Clement D. M. Hindley, President of the Institution of Civil Engineers, in the chair and supported by twelve past-presidents and the same number of members of council, welcomed the Ambassador. Mr. Kennedy then presented the diplomas. Mr. Asa Binns, President of the Institution of Mechanical Engineers, who was accompanied by fourteen past-presidents and thirteen members of his council, expressed the thanks of both institutions to the Ambassador for the honour he had conferred upon them by attending in person to make the presentations.

BRITISH TECHNICAL JOURNALS AND FOREIGN CIRCULATION.

In the House of Commons last week, Mr. Garro-Jones asked the Secretary of State for Air whether he proposed to continue to allow the regular dispatch to Germany of aviation journals with their technical articles, service news and large volume of circumstantial information; whether he was aware that one of the journals recently gave, among other things, the full names and addresses of Air Ministry manufacturers and details of the goods they supplied; and whether any German publication provided for us corresponding information. In reply, Captain Balfour said that he was glad this matter had been raised, because it was desirable to emphasise that it was not our policy to restrict the dispatch abroad of British aviation journals. They were of high repute and provided a means of making known to the world the excellence of our products. Since the war, arrangements had been made to prevent the publication by the Press in general, including these journals, of information likely to be of value to the enemy. It was true that a recent publication contained information on the lines indicated, but there was nothing in it of a secret nature. German publications, even in peace time, had never furnished information comparable with that contained in British journals. The remarks of Captain Balfour are equally true in a wider application. It is essential for the future well-being of the nation that British technical developments should be recorded and made known as widely as possible, even in war time. Responsible journals, properly used, can be of the greatest assistance both to the Government and industry in stimulating the export trade drive. We are glad that the Government realise this and hope that they will impress this aspect upon those Service officials who still seek to ban information in whole categories, without reference to the circumstances of particular cases.

THERMODYNAMICS AND THE LOWEST TEMPERATURES.

THE thirty-first Kelvin lecture was delivered before the Institution of Electrical Engineers on Thursday, April 25, by Dr. C. G. Darwin, who took for his subject "Thermodynamics and the Lowest Temperatures." At the commencement of the meeting, the Faraday Medal for 1940 was presented to Dr. Alexander Russell, F.R.S., by the President, Mr. Johnstone Wright.

In his opening remarks the lecturer said that the particular branch of physics with which he proposed to deal, the attainment of great cold, in itself constituted an epitome of the subject of thermodynamics. Thermodynamics went beyond the familiar principles of ordinary dynamics and an extra principle was, therefore, required in order to be able to work it. This principle was that of the equipartition of energy, which laid down that in a mixture of gases the average energy of a molecule of one gas would be equal to the average energy of the others, no matter in what proportions they were mixed together. When a number of gases were intimately mixed, however, they were thereby compelled to come to the same temperature. The average energy of equipartition could, therefore, be identified with the temperature. It might be shown, in fact, that it was identical with the temperature measured on Kelvin's absolute scale. The principle of equipartition implied the celebrated law of Dulong and Petit that the specific heats of equal numbers of atoms of different substances were the same. Though this law held for most substances, there were certain puzzling exceptions. For instance, the diamond had a much smaller specific heat than it should have. Moreover, the law implied that just as much energy should be taken to raise a body from 1 deg. K. to 2 deg. K. as from 273 deg. K. to 274 deg. K., whereas it had been found that at these low temperatures the specific heat of all substances became very small, the diamond only differing from the rest in that the drop started earlier. This was fully explained by the quantum theory and was due to the fact that energy could not be taken up by the atoms in arbitrary amounts, but only in definite units. The problem was complicated a little by the fact that it was not the separate atoms which constituted the units on which the energy was placed, but combinations of them in the form of elastic waves of vibration. The shorter waves that required large doses of energy were frozen out, all the energy going to the longer waves which could accept it in smaller quantities. It was this which caused the specific heat to be much less at low temperatures.

Continuing, the lecturer said that in all cases of refrigeration by vapours followed the same principle. By some means or other a machine was arranged so that certain components of the system lost energy by doing work on something outside the system. The balance of equipartition between them and the other parts of the system was therefore upset and when fresh equipartition was again set up it was at a lower value; in other words, the body was cooled. With the help of various types of machine based on these principles, temperatures down to a little below 1 deg. K. could be reached. At about 0·8 deg. K. the process failed, for the practical reason that the vapour pressure, which was operative in extracting the energy, had become very small. The only way of utilising this small amount of vapour would be to employ a much larger machine with a greater heat capacity and correspondingly difficult to insulate. Moreover, at 1 deg. K. the specific heat of all substances had become very small. The consequence was that when a certain amount of energy was extracted from a substance the temperature dropped very much more than it would have done if the specific heat had retained its value from ordinary temperatures. At these temperatures, too, certain metals and compounds became super-conductive, and, in some cases, acquired greatly enhanced magnetic properties which made the next stage in refrigeration possible.

The fact that magnetisation in a given field would go up as the temperature went down suggested a method by which, conversely, the temperature could be altered. The process was first proposed by Debye and independently by Giauque, who cooled down gadolinium sulphate or iron alum, in the form of a powder, with liquid helium. The substance was next placed in a strong magnetic field, as a consequence of which it began to heat up again and thus heat was absorbed by the liquid helium. The helium was thus removed so as to insulate the specimen and the magnetic field was cut off. As a consequence, the temperature dropped immediately to a very low value. Though technically the process was, of course, very difficult, this drop in a single step to the lowest temperature was in some respects much simpler than the elaborate process of pumping and re-pumping of vapours that had to be done in the earlier stages of refrigeration. What occurred was due to the fact that when a magnet was placed in a magnetic field it oscillated with a certain frequency, which diminished as the field weakened. If, therefore, the paramagnetic material was put into a strong field, the particles acquired more energy than was justified by equipartition and this they shared out so that the specimen heated up. This heat was absorbed by the liquid helium and the magnets were left with the equipartition energy of the liquid helium. When the field was weakened, the magnets lost most of their energy and retained very much less than the equipartition amount. They tried to restore equipartition by borrowing energy from other parts of the system, and so the temperature was lowered. This process was effective at deep temperatures for two reasons: Firstly, the magnetic susceptibility became much greater, so that the magnetic fields attainable became much more efficient, and, secondly, the specific heat became much smaller, so that a given extraction of energy changed the temperature more. In this way it came about that it only took a single stage to lower the temperature from about 2 deg. K. to about 0·003 deg. K.

There had been several schools of workers in this field. Giauque in America was the first to apply it, and he had made a detailed study of the properties of matter round about 0·1 deg. K. De Haas, of Leyden, had got down to about 0·003 deg. K., and Simon, of Oxford, to about the same. In addition to obtaining such temperatures, it was necessary to know what they were on the absolute scale. This called for more elaborate work, but the problem had been facilitated by the fact that the heat losses at these low temperatures could be made very small. The system could, therefore, be approximated much more easily to the ideal thermodynamic engine of Carnot and the temperature could thus be measured directly. Pre-eminent on this side of the problem had been the work of Simon and his collaborators, who had fixed the absolute temperature scale with considerable accuracy down to 0·01 deg. K. The properties of matter at these temperatures were interesting. There was to all intents and purposes no vapour left. It was this that made the heat insulation so good. Then the specific heat became very nearly simply that of the magnets, since the other parts had so little that they hardly counted. As the temperature dropped, moreover, each little magnet forming the system began to line up and cumulatively to exert forces on each other, so that each unit reacted to the total field acting on it.

The old theory of these local fields was that of Lorentz, according to which the susceptibility should be inversely proportional not exactly to T, but to $T - \theta$, where θ was a calculable temperature, which for most substances should be in the region of 1 deg. K. Below this temperature the substance ought to be capable of becoming a permanent magnet. Experiments failed, however, to find any permanent magnetism at the predicted temperature θ, though there was a faint and rather doubtful suggestion of it at a considerably lower temperature. Lorentz's theory was, however, now known to be too simple, and though the full answer was not known, it was clear that there was no reason to expect the onset of permanent magnetism at the critical temperature. Presumably, it would not come at any point above the absolute zero.

If, went on Dr. Darwin, it was so comparatively easy to get down to 0·003 deg. K., what stopped a further advance? The answer was that for each substance there was a sort of barrier preventing further chilling. This barrier temperature could be lowered by taking a more dilute crystal, for example, by mixing the iron alum with some non-magnetic alum, but the process would break down in the same way as occurred in the production of cold by vapours. The diluted crystal would have less little magnets available for giving up their energy and so a larger specimen or a stronger magnet would be necessary to obtain even the same temperature drop. To get much below 0·003 deg. K. a great bulk of inefficient material in a strong magnetic field (and, of course, in a vacuum) would be necessary, and this was technically impracticable. The method of demagnetisation by means of paramagnetism was exhausted at a little above one-thousandth of a degree.

This was more or less how matters stood at the moment, but it was not necessarily the end. It had been suggested that the magnetism in the nucleus of an atom might be utilised by a similar process to that first described to get down to something like one-millionth of a degree. A good many atoms had magnetic nuclei, and their strengths were about one-thousandth of those that had been considered above. This was just what was wanted. The proposal was to take a diamagnetic salt of a metal of this character, but the experiment would not be easy. It would be necessary to cool the specimen to the thousandth in a magnetic field by contact with a paramagnetic, which had already been cooled so far by being taken out of the field. For this a long heat-conducting channel would be essential, and this channel, probably of liquid helium, must itself also be lowered to the temperature. Theory, however, suggested a curious difficulty. For the process to work it was not sufficient merely to get the energy out of the magnets, but these magnets must also be able to borrow the energy from the rest of the system so as to restore equipartition; if they did not, the temperature could not be said to have been really lowered. Now theory showed that this rate of borrowing depended enormously on the temperature. At 1 deg. K. it was instantaneous, while at a thousandth it took seconds or minutes, but at a millionth it might easily take a million years. The heat insulation had, so to speak, become so good that different parts of the same molecule could be at different temperatures for a million years without the heat flowing from one part to the other. The structure of a metal was very different from that of a salt, in that however low the temperature there were always electrons moving about in it at high speeds. These electrons succeeded in bringing about equipartition quite rapidly. It seemed likely, therefore, that perhaps in a few years by the use of a metal in which the nuclei had a magnetic moment, it might be possible to reach temperatures down to perhaps a hundred-thousandth, perhaps a millionth of a degree.

It did not seem likely that the properties of matter at these temperatures would be very different from those already found at a thousandth. It was possible that other metals might become superconducing, but it was doubtful whether the paramagnetics would become permanent magnets owing to the slow rate at which they would come to equipartition with the cold body. Simon had, in fact, suggested that the whole idea of temperature would fade away. For temperature to have a practical meaning it must be possible to take the temperature of a body with a thermometer. This implied that the thermometer must be smaller than the body of which it was measuring the temperature, otherwise it would itself disturb the body's heat. There was, however, now so little energy in the body that most of the time the thermometer would have none at all and then occasionally too much; so that, if we wanted to speak usefully of temperature at these very low temperatures, we must take a large body and the lower the temperature the larger the body must be.

THE INSTITUTION OF MECHANICAL ENGINEERS.

AN extra general meeting, arranged by the Internal Combustion Engine Group of The Institution of Mechanical Engineers, was held at Storey's-gate, St. James's Park, London, S.W.1, on Friday, April 26. Wing-Commander T. R. Cave-Browne-Cave, C.B.E., chairman of the Group, presided.

OIL-ENGINE FUEL INJECTION.

The paper presented for discussion was entitled "Fuel Injection in Oil Engines in Relation to Combustion," and was read by Mr. G. W. A. Green, B.Sc. The injection system dealt with in it was that of the jerk pump, and the relationship between the design of fuel injection equipment and the design of the engine on which it was used was shown. The nozzle, considered as an orifice, was dealt with in its relation to the combustion chamber, and the hole-type and pintle-type nozzles described. Other sections of the paper included the action of the differential needle valve, and its quick action with good "chattering"; the design of "restricting" or "delay" type nozzles; the need for "unloading" the delivery pipe, with consideration as to size and surging; the action of a pump plunger and barrel of the ported type; and the combined effect of pump plunger and delivery valve. A classification of combustion chambers was put forward; orifice diameters considered; the selection of a suitable pump for specific nozzles dealt with; and specific ratios for assessing pump action in relation to the engine and nozzle given. Consideration was given of the limiting capacity of an atomiser and the maximum pressure of injection.

Mr. C. B. Dicksee opened the discussion by remarking that unloading was the secret of success in the high-speed engine since it overcame imperfections in the nozzle, such as a minute leak which might cause "coking-up," with subsequent trouble. Better results were sometimes obtained for a short period, but not maintained, with some other system than unloading. For a variable-speed engine the increase in residual pressure was sometimes of value in giving an automatic injection in advance, but in the present state of nozzle manufacture it might give trouble. He thought the resistance type of unloading valve shown in the paper looked elaborate and costly. He could not agree with the author's statement that it was impracticable to use valves with different unloading volumes for different engines. Nor could he agree that the fuel pipe was invariably a nuisance. It was a matter of suitable length being employed and a pipe of this kind could be advantageous in modulating the injection. On small high-speed engines he had found from experiment that if the pipes did not exceed 500 mm. that there was very little difficulty, beyond that trouble might occur from residual pressures and other causes. He could not agree, moreover, with the statement that the combined pump and nozzle did away with the necessity for the differential valve since, without this valve, it was impossible to get an initial rate of pressure rise at the nozzle which would give satisfactory atomisation during the first degree or two of the atomisation period. Experiments by the Bureau of Standards at Washington had shown that atomisation was the result of friction between the fuel jet and the surrounding atmosphere, and, unless the velocity was sufficient, none took place. Without a differential nozzle in the case referred to, the pressure would rise relatively slowly and the atomising velocity would not be obtained until the pressure reached a certain figure.

Mr. H. O. Farmer observed that the author had said very little about the volume of fuel below the delivery valve—the untrapped volume. The ratio of trapped volume to fuel injected should be controllable as this had a big effect on the performance of the pump. He inquired as to the effect of the ratio of the trapped to the untrapped volume of fuel, particularly as to the effect over the load range. As the maximum injection pressure was proportional to the quantity of fuel injected, the work done by the delivery valve varied according to the engine load, so that at light loads it would unload the delivery pipe to a different pressure from that at full load. He would ask if there was any way of making allowance for this. Should not, where possible, the pressure in the fuel injection system be kept down to a reasonable figure to avoid excessive cam wear? As to maximum fuel-injection pressure, he had always assumed this to be dependent on the rate of plunger movement and the area of the nozzle, and the author had said that if the tension on the atomiser-needle spring were increased the pressures throughout the cycle went up. This was not very obvious, and further information would be useful.

Dr.-Ing. G. V. Lomonosoff said that for many years he had shared the author's opinion that in any Diesel engine the injection equipment was an integral, and very important, part of the engine, and not a secondary auxiliary. Its design considerably influenced the phenomenon of combustion, which was the basic process of any heat engine. The paper, therefore, greatly interested him, though it did not deal with the influence of the design of the injection equipment on combustion. Experiments in that direction were, however, quite possible and promising. It might be argued that the author had selected a statistical and not an experimental method, but the absence of information concerning the conditions of combustion in the engines greatly decreased their practical value.

Mr. A. F. Plint, remarking that mention had been made in the paper to an arrangement of pump in which the spilt fuel was led back by separate channels to the supply tank, asked whether this had been used to any considerable extent. He had had one curious experience with it in a small engine with a rather long suction pipe. The engine invariably ran for 23 minutes and then failed, due to a gas bubble in the pump. The defect was cured by putting an air vessel on the suction pipe, near the pump. Account might, perhaps, be taken of the relative diameters of the needle and pump plunger. He had been concerned with a 70-mm. by 120-mm. two-stroke engine, which normally used a 6-mm. fuel pump and an atomiser with a 6-mm. needle. The object was to produce about 1 h.p., and the engine was run at 1,050 r.p.m. in a test of nearly 200 hours. The consumption was not good,

per se, being 1 gallon in 11½ hours, and the injection working out at 6·25 cub. mm. The theoretical pump stroke was 0·22 mm. and the injection period 1·25 deg. It would seem that the author's ideas on suction ports and spill ports were correct, since the injection took place when both were opened. After reading the paper he examined the effect of the needle and found the lift to be 0·36 mm. As the diameter was 6 mm., this lift increased the volume by more than the amount which was required to be injected, which meant that the injection period was between 3 deg. and 4 deg. instead of 1·25 deg. It seemed that when dealing with small engines, in particular, some attempt should be made to relate the size of the pump plunger and the needle.

Dr. J. Bujak, commenting on the reference in the paper to the position, circularity and parallelism of the holes in "hole"-type nozzles, asked whether the author held any views regarding the influence of the sharpness of the inner edge. This edge, since the holes were always drilled from outside, would be sharp and there might even be a burr. When engaged on the manufacture of this type of nozzle he used to test the precision and uniformity of the holes by measuring the amount of fuel discharged by each hole of the nozzle. The flow was continuous and was set up by maintaining an air pressure of ten atmospheres in the fuel tank. The calculated coefficient of discharge was so low that means were sought to chamfer the inner edges of the holes. A fuel, loaded with very fine emery powder, was discharged through the holes for a period of a few hours, but no appreciable change in the flow coefficient was afterwards observed. The author had mentioned three atmospheres as the minimum spring loading of a resistance-type unloading valve. In this connection, he might mention that, apart from the pressure due to the pump delivery, the fuel column in the suction pipe might result in astonishing phenomena. A case might be cited in which both the delivery valve of a pump and a check valve in a nozzle being lifted by the surge of the inertia effect in the suction pipe. This surging caused a second injection, in spite of the fact that the spring loading of both valves exceeded five atmospheres. The second injection occurred at the end of the suction stroke of the plunger, which point corresponded to the bottom dead-centre of the two-stroke engine concerned, so that the amount of fuel injected the second time was lost to the combustion. The statement that the pressure loss in a pipe was the velocity head plus the loss due to friction was only true in the case of continuous flow, which prevailed more or less in the middle of the injection period; at the beginning of that period it seemed that considerable acceleration of the fuel column occurred. He had measured the peak pressures on a pump delivering fuel to a pipe 2 mm. in diameter by 3 ft. long, and discharging freely into the atmosphere without any nozzle. The fuel velocity in the pipe, calculated from the plunger velocity, was about 0·35 cm. per second, and the maximum pressure on the pump rose to about 100 atmospheres. This pressure was partly changed into velocity head and partly used to overcome friction, but the largest part of it was needed to accelerate the fuel column. When, however, a nozzle was fitted, having a release pressure of 130 atmospheres, the maximum pressure on the pump rose to about 150 atmospheres.

Professor S. J. Davies said the remarks in the paper on "chattering" were interesting. The author suggested that it was necessary for the nozzle valve to rise and fall over its full travel, but hydraulic relief valves, which were also given to severe chattering, did not so behave. In tests at King's College it had been found that, when the needle valve rose and fell rapidly in the manner sometimes called "valve bounce," the movement always had a corresponding fluid-pressure variation. This, he considered, was the dominant factor and the mass and inertia of the valve were unimportant. He did not understand the author's statement that chattering was desirable. He agreed with the author that the trapped volume must be reduced, but the distribution of the trapped volume—whether in the pump, in the pipes, or at the nozzle—was important. The author, in dealing with surges in the delivery pipe, had hardly emphasised sufficiently the predominance of the transmission of pressure waves in the pipe throughout the whole of the injection process. Professor Davies concluded by outlining a programme which, he suggested, manufacturers of injection equipment might carry out. Experiments might be made with a particular size of pump plunger, a particular type of nozzle and a particular pipe line, and the variation of injection characteristics noted as the nozzle pressure was varied. Another series might show the effect of varying pipe lengths.

Mr. R. J. Welsh thought that too much emphasis was often laid on the chattering of the fuel valve. This phenomenon was a good test of a properly-made valve, but to design a valve so that it would chatter was incorrect procedure. The counsels given by the author on the matter of plunger rates were too wide to be of use. It was difficult to choose a plunger rate with exactness because it was bound up with the amount of fuel required by the engine.

Mr. A. T. J. Kersey confined his remarks to the curves of orifice area and plunger rate in relation to piston-swept volume. These, he said, seemed to indicate the author's main conclusions with regard to co-ordinating the various factors. Few people, he thought, would agree that the curves represented average results or that they showed desirable proportions. He thought that logarithmic plotting gave a wrong impression of the real positions of the points through which the curves were plotted.

Mr. Arthur F. Evans briefly reviewed the history of fuel injection and was of opinion that the advent of the jerk pump, with its rectifier, the differential injector, had paved the way for modern developments. Later it was discovered that the fuel delivery pipe was a factor of some importance. There were still faults in injection systems and when these were eliminated it might be found there was a better way of burning oil and obtaining power.

Mr. V. H. F. Hopkins remarked that the author had stated that nozzle orifices were, in practice, either circular or annular, *i.e.*, the issuing sprays were mostly of an acute conical form. The engine builder was thus handicapped by the difficulty of obtaining special sprays more suitable for a particular combustion chamber. One Continental oil-engine manufacturer, who made his own fuel equipment, employed a fan-shaped spray and with such a nozzle, which was cheaper to make than those under discussion, a consumption of 0·34 lb. of fuel per brake horse-power-hour had been recorded on an engine of only 700 c.c. capacity. There was also a nozzle of the open type, which seemed worthy of more attention in its individual development for a particular combustion chamber. Another Continental engine-builder had used a poppet type of nozzle, which gave very satisfactory results so long as it remained in good condition. He agreed with the author that needle chattering was indicative of a good nozzle.

Mr. P. H. Smith observed that the author had not touched upon the subject of wear and tear on the valve gear, such as the cams and camshaft gear wheels or chain sprockets, and suggested that a heavy flywheel on the fuel pump shaft might be a help, particularly in two-stroke engines.

Mr. Green, in reply, thought Mr. Dicksee's strictures on the resistance type unloading valve were not justified. It was little more complicated than other types and needed almost no lapping. For high-speed engines a pipe 500 mm. long was ample. He would like to see less. A differential valve was unnecessary in a combined pump and nozzle, because the volume of trapped fuel could be reduced almost to nothing by careful design. Mr. Farmer and Mr. Smith had referred to driving-gear wear with high injection pressures. This tendency could be adequately allowed for in design. Mr. Plint's reference to the use of separate channels for the return of the spilt fuel to the supply tank indicated a complicated arrangement with a more costly pump. In reply to Dr. Bujak, he would say that, while the contour of the inlet end of the injection hole was important, he thought that of the outlet end was more so. The remarks about the secondary injections from surges in the suction pipe were very interesting, but such a condition could probably not arise in an ordinary jerk-pump system with a differential needle valve. The use of an unloading valve and the increase of the unloading effect sometimes made secondary injections worse by apparent increase of the violence of the surge. Professor Davies' suggestion for a research programme was sound, but impracticable, the latter owing to the number of variables involved. He could not agree with Mr. Welsh that the importance of chattering had been over-emphasised, but he would say that the chattering he had in mind was that occurring when an atomiser was tested on a hand pump with a very low fuel-delivery rate; the nozzle did not and should not chatter on the engine.

He noted that Mr. Kersey disagreed with the plotting of the curves at the end of the paper. These were admittedly tentative. He gave them to set the ball rolling and hoped that others would contribute more data so that, in time, a more reliable set of curves could be built up. He had used logarithmic plotting to open out the points at the lower ends of the curves, which points would otherwise be very close together. Mr. Smith's suggestion of a flywheel on the fuel-pump shaft might, in certain cases, be helpful, but its fitting was liable to set up serious synchronous vibrations.

THE LATE MR. ROGER T. SMITH.

MR. ROGER T. SMITH, whose death, we regret to record, occurred in London on Sunday, April 28, at the age of seventy-seven, was well known as a leading advocate of the extended use of electric traction on railways and as being responsible for several schemes of conversion, both in this country and abroad.

Roger Thomas Smith was born at Forest Hill, London, on March 23, 1863, his father being T. R. Smith, who was then professor of architecture at University College, London. He was educated at Mill Hill School and University College, London, and afterwards served his pupilage with Messrs. Hawthorn, Davey and Company, Limited, Leeds. On the completion of his articles he joined their staff as an assistant and supervised the erection of large waterworks pumping plants for the East London, Weston-super-Mare and Wolverhampton waterworks and for the Hereford sewage works. He then went to India as engineer for Messrs. Easton, Anderson and Goolden, acting for them in the installation of waterworks plant at Agra, Allahabad, Benares and other places.

On his return to England in 1897 he became, after further work at University College, one of the resident engineers, under Sir Alexander Kennedy, for the erection of the Davies-street generating station of the Westminster Electric Supply Corporation, and then served for a time in Antwerp as technical manager of La Compagnie Hydro-Electrique Anversoise, which had been formed to supply hydraulic power and electric light to that city. While in Belgium he also designed and carried out a scheme for supplying electricity to the Commune of Brecht. He subsequently became a member of the staff of Messrs. Kennedy and Jenkin, consulting engineers, and was employed by them in carrying out electric lighting and tramway schemes in several towns in the north of England and Scotland, and on the equipment of the Hill of Howth Railway in Ireland. He was also in charge of the Parliamentary work connected with the electrification of the London County Council Tramways, and assisted in the actual carrying out of the scheme on the conduit system, until he went for the firm to Buenos Ayres, where he was in charge of the conversion of 64 miles of horse tramways in that city to electric traction for the City of Buenos Ayres Tramways Company. He was subsequently engaged for Messrs. Kennedy and Jenkin in the electrification of the Hammersmith and City Railway, jointly owned and operated by the Great Western and Metropolitan Companies. This included the erection of a generating station at Park Royal.

On the completion of this work in 1905, he was appointed electrical engineer of the Great Western Railway, a position he held until he reached the age of retirement in 1924. During that period he was concerned with a number of interesting contracts, including the installation of electrically-operated machinery at the goods depots at Bristol, Cardiff, South Lambeth, Birmingham and Halesowen, as well as the extension of electric lighting to the stations and other buildings on all parts of the system. He also installed an extensive electrically-worked conveyor system at Fowey, Cornwall, which enables the china clay, which is brought down by tram from the neighbouring quarries, to be loaded expeditiously and efficiently for sea transport. He was responsible for the replacement of gas by electric lighting on the passenger rolling stock. In spite of his keen advocacy of electric traction, however, it only fell to him to supervise one scheme of this kind, that being the construction and

electrification of the Ealing and Shepherds Bush Railway.

On his retirement, Mr. Roger Smith became a partner in the firm of Highfield and Roger Smith, who, *inter alia*, acted as consulting engineers for the Central England Electricity Scheme of the Central Electricity Board. He was elected an associate-member of the Institution of Civil Engineers in 1889 and transferred to the class of member in 1918. In 1912, he was awarded the Stephenson Gold Medal of that Institution for a paper on the electric lighting of railway trains. He was also a member of the Institution of Mechanical Engineers, having been elected in 1896. His connection with the Institution of Electrical Engineers began in 1907, when he was elected a member. After service on the Council and as a vice-president, he became president in 1919. His presidential address was mainly devoted to the subject of electric traction, and he prophesied that there would be considerable development in this direction, both on account of its advantages, but also because it was becoming the fashion. Though this prophecy has to some extent been fulfilled by the operations of the London Passenger Transport Board and, generally speaking, in the many schemes that have been carried out abroad, the Southern Railway is the only one of the British main-line systems which has adopted this solution as a means of improving the services they provide for the public. For this state of affairs there are many reasons—some technical, some financial and some to adopt Roger Smith's phrase, "fashionable," and these were discussed by him in the presidential address which he delivered before the Institute of Transport in 1927.

Mr. Roger Smith was a member of the committee, appointed by the Ministry of Transport, which reported on the electrification of railways in 1921, and was a delegate to the International Railway Congress held in Rome in 1922 and in London in 1925. He was president of the British Section of the Société des Ingénieurs Civils de France in 1923, and for a number of years was engineering member of the Senate of the University of London. He was also a member of the American Institute of Electrical Engineers and was closely connected with the work of the British Standards Institution, the International Electrotechnical Commission and the World Power Conference. He was elected an honorary member of the Institution of Electrical Engineers in February of the present year.

THE LATE MR. F. E. POLLARD, M.B.E.

We regret to record the death, on April 11, as the result of a road accident, of Mr. F. E. Pollard, M.B.E., Senior Engineering Inspector in the Factory Department of the Home Office. He was 59 years of age and had been in the Department for 31 years.

Frederick Ernest Pollard was trained as a textile-machinery mechanic. He was awarded a Whitworth Exhibition in 1903, and studied at the Royal College of Science, where he received the diploma of A.R.C.Sc. (London) and subsequently remained for a period as a demonstrator. In 1909, he was appointed an Inspector of Factories, but his service in this capacity was interrupted by the outbreak of war in 1914. He received a commission as lieutenant in the Royal Naval Volunteer Reserve in 1915, being attached at first to the Royal Naval Air Service. Subsequently he was transferred to the Royal Air Force, from which he was demobilised in 1919 with the rank of Major. On returning to the Home Office, he resumed his former duties as an Inspector, remaining in this grade until 1926, when he was transferred to that of Engineering Inspector. Ten years later, he was promoted to Senior Engineering Inspector, in which position his skill and experience were of great value in the preparation of the safety clauses of the Factories Act, 1937, and in his work as a member of the Mechanical Industry Committee of the British Standards Institution. He was also a member of the Committee appointed in 1934 to consider the precautions necessary in the operation of kiers, the report of which led to the introduction of the Kiers Regulations, issued in 1938.

THE LATE DR. ALFRED J. AMSLER.

News reached us, just too late for inclusion in our last week's issue, of the death of Dr. Alfred J. Amsler, which occurred at his home in Schaffhouse, Switzerland, on April 2. Dr. Amsler, who was in his 83rd year, was senior partner in the firm of Messrs. Alfred J. Amsler and Company, of Schaffhouse, and was responsible for the design and development of numerous machines and apparatus for testing materials. His scientific and mathematical knowledge was also applied to the perfection of many widely-used instruments, including integrators, hydraulic current meters, railway dynamometers, etc. We hope to deal with his attainments more fully in a subsequent issue of ENGINEERING.

LETTER TO THE EDITOR.

MODERN HIGH-PRESSURE WATER-TUBE BOILERS.

TO THE EDITOR OF ENGINEERING.

SIR,—Your issue of March 8 contained an article, on pages 246 to 248, entitled "Modern High-Pressure Water-Tube Boilers," this being a summary of a paper on "High Pressure and Forced Circulation Boilers" recently read by Dr. R. Pendennis Wallis, M.Sc., M.Inst.C.E., before the London Technical Group of the Electrical Power Engineers Association. On page 247, it is stated that "Although various alloy steels present advantages from the point of view of creep, these may be offset by a lower thermal conductivity; a 0·26 per cent. carbon steel will transmit 400 B.Th.U. per square foot per hour per degree Fahrenheit per inch thick; a carbon steel with 0·5 per cent. molybdenum will transmit only 240 B.Th.U. and an 18 per cent. chromium and 8 per cent. nickel steel only 114 B.Th.U. Molybdenum steel is being increasingly used for superheater tubes, but the figures just cited show that the temperature drop through the metal for a given heat transfer is more than 50 per cent. greater than with an ordinary steel."

Relevant temperatures range from 850 deg. to 1,000 deg. F., and the difference in thermal conductivities indicated by Dr. Wallis do not agree with determinations made in this Department. We give the following as typical figures:—

Material.	Thermal Conductivity at 930 deg. F.
0·26 per cent. carbon steel.	265 B.Th.U. per sq. ft. per in. per hr. per deg. F.
Low C steel, with 0·5 per cent. Mo.	265 " " "
18/8 Cr-Ni stainless steel.	150 " " "

Therefore, at the operating temperature indicated we cannot but express disagreement with the statement made by Dr. Pendennis Wallis, and say that, on the contrary, it is possible to take full advantage of the higher creep strength of molybdenum-steel superheater tubes, compared with 0·26 per cent. carbon-steel tubes, without any loss in thermal efficiency.

Yours faithfully,

THE UNITED STEEL COMPANIES, LIMITED.
CENTRAL RESEARCH DEPARTMENT.
J. A. JONES.

Stockbridge,
April 26, 1940.

MACHINE-TOOL TESTS AND ALIGNMENTS.

THE letter printed below has been issued by the Machine Tool Trades Association in connection with the brochure entitled *Acceptance Test Charts for Machine Tools*. We comment on this matter in our leading article on page 463.

TO MEMBERS OF THE MACHINE TOOL INDUSTRY.

DEAR SIR(S),—Representations have from time to time been made by this Association suggesting to the Institution of Production Engineers that joint consideration of the above subject should be deferred until after the war. It was felt by the Association that those members of the machine tool industry best qualified to enter into joint deliberations on this subject could not be spared from their task of contributing their utmost to the national effort by way of increasing the production of machine tools.

Notwithstanding these representations and the fact that the British Standards Institution did not regard it as practicable at the present time to proceed with the question of preparing any British Standard Test and Alignments for Machine Tools, the Institution of Production Engineers, in collaboration with the Institution of Mechanical Engineers, have published Acceptance Charts for Machine Tools, and have expressed their intention of publishing still further charts to cover a wide range.

In these circumstances, the Council of the Association, at a meeting held on April 3, decided that they had no other alternative than to make it known to the machine tool industry that the Association have had no part in the preparation of these Acceptance Charts, and must advise their members not to accept orders conditioned on conformity with these charts.

It is regarded as elementary that publication of these charts should not have taken place without the fullest concurrence of the industry, and that the present time is an impossible one in which to obtain such concurrence.

Yours faithfully,

W. J. MORGAN,
Secretary.

April 9, 1940.

THE NEWCOMEN SOCIETY.

AT the concluding meeting of the 1939-40 session of the Newcomen Society, held at the Science Museum on April 24, two papers were read, in accordance with the usual practice: one from the English part of the Society, and one by an American member. The first, jointly contributed by Mr. and Mrs. R. Wailes, was a description of a post mill in Picardy. This mill, which is the last working post mill in the department of the Somme, was built in 1630 and is typical of the millwrighting practice of the district. A striking feature is that it is supported on four cross-trees, 10 in. by 12 in. in section, instead of the usual two, and has no less than sixteen quarter bars in pairs, instead of the eight usual in France and the four in England. The post is 27 in. square at the base, tapering to 22 in. at the top. The mill has two wind indicators. There is only one pair of stones, but these are the largest noted in any French post mill, being 6 ft. 3 in. in diameter. The second paper discussed, "The Earliest Industrial Use of Coal," was by Dr. T. T. Read, Vinton Professor of Mining Engineering at Columbia University, New York. Dr. Read surveyed statements found in the early records of many countries, which might be thought to relate to the use of coal, special reference being made to Chinese writings. The evidence that there was an important and profitable iron industry in China long before the Christian era is unimpeachable, Chinese iron castings 1,500 years older than the oldest European specimens being still in existence. Whether this iron was produced with coal as fuel is not known, and seems improbable, since the weight of opinion is that coal did not come into general use in China before the Fourth Century A.D. The conclusion arrived at by Dr. Read was that coal was first used as fuel, not by culturally advanced people of ancient times but by natives who had no literature. It is unlikely, therefore, that it will be possible to establish a date or place regarding its first use industrially.

STEEL SUPPLIES AND ELECTRICITY UNDERTAKINGS.

THE Electricity Commissioners have been designated by the Ministry of Supply under the Iron and Steel (No. 8) Order, 1940, as the Department responsible for the authorisation of supplies of steel required by generating stations, the grid, and electrical distribution systems. Applications by electricity-supply undertakings for the issue of steel required for any contracts or orders already placed but not yet completed, and for which the necessary steel has not yet been obtained, or for any contracts or orders which it is proposed to place, should accordingly be made to the Electricity Commissioners. These applications should state the general purposes for which the steel is to be used, and the quarterly period during which the contractor or supplier requires delivery. It should also state the weight of steel required and be accompanied by a certificate stating that this amount represents the minimum necessary for the purpose in question. Separate particulars should be given where the steel is required for building construction, as the Ministry of Supply have made a separate allocation for this purpose.

Undertakings are specially asked to note that applications for an allocation must be made by them and not by their contractors, and that a separate application must be made in respect of each separate contract or order. In cases where the Commissioners are satisfied that the steel should be made available and the Order so requires it, they will authorise the use of their departmental symbol (E.C.) to identify the order proposed to be placed by the undertakings as having been given on account of the allocation made to the Commissioners. The authorisation will also indicate the Departmental reference number, the period number for delivery, and the total tonnage of finished steel allocated. Special attention is drawn to provision in Direction No. 1 appended to the Minister of Supply's Order that any person who, by virtue of an authorisation under that paragraph, acquires any steel shall not use it for any purpose other than that for which the authority was given. In conclusion, the Commissioners reiterate the need for the utmost economy in the use of all materials and state that they feel sure that all electricity undertakings will appreciate that it is in the national interest that the scheme should be worked successfully. They, therefore, rely on the ready co-operation of undertakings to supply the information requested and to refrain from demanding delivery of supplies earlier than is really necessary.

Certain materials, such as bolts and nuts, screws, plate, tin plate, etc., not exceeding a specified quantity nor 10*l.* in value (further purchases of material in each category not being permitted in the same week) may until further notice be acquired without specific authorisation.

LABOUR NOTES.

THE claim of the three trade unions of railwaymen—the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Railway Clerks' Association—for an increase of wages, was submitted to the Railway Executive Committee in London on Friday last week. A war advance of 6*s.* a week is desired for the operative staff and one of 15*l.* a year for the salaried staff. In December last, the unions applied for an increase of 10*s.* a week and, after negotiations, agreed to accept 4*s.* a week. The 6*s.* now asked for is regarded as the balance of the original claim. The Committee promised to give their reply as soon as possible.

At the end of March, 2,035 members of the Boilermakers' and Iron and Steel Shipbuilders' Society were "signing the books," as compared with 3,020 at the end of February. During March, the number of members on superannuation benefit decreased from 3,599 to 3,580, and the number on sick benefit from 2,225 to 1,439. In February, the expenses amounted to 3,664*l.* 3*s.* 1*d.*; in March, which had to bear five weeks' outlays, they were 5,776*l.* 8*s.* 10*d.* There was a net increase of 940 in the membership.

Writing in the April issue of the *Report* of the Boilermakers' and Iron and Steel Shipbuilders' Society, Mr. Hodgson, the general secretary of the organisation, says:—"I referred last month to a meeting which we had had with the Minister of Labour at which he had made known his anticipated labour requirements. Figures were produced showing the number, in their respective categories, signing at the Employment Exchanges. These figures coincided with our own and included over 1,600 hand riveters for whom, he said, there appeared to be little demand. This suggested an attitude which could not be accepted, as these members all have skill and experience which are invaluable and must be utilised. We had previously, on several occasions, mentioned this matter to the shipbuilding employers when in conference, and since the meeting above referred to we have had a further discussion with them. They assured us that they would give every assistance in placing our idle members in suitable employment and steps in that direction have already been taken. In some districts our District Delegates, together with the firms' representatives, have interviewed men, and, as a consequence, suitable arrangements have been made for them to commence work. This, no doubt, to a considerable degree, accounts for the decrease in our unemployed figures. There is more yet to be done in this direction."

According to *The Ministry of Labour Gazette*, the number of insured persons between the ages of 16 and 64, recorded as unemployed in Great Britain and Northern Ireland at March 11, represented 7·7 per cent. of the total number of insured persons between the ages of 16 and 64 at July, 1939, as compared with 10·3 per cent. at February 12, 1940. At March 13, 1939, the percentage unemployed was 12·0. For persons insured under the general scheme, the corresponding percentages were 7·8 at March 11, as compared with 10·2 at February 12 and 12·2 at March 13, 1939. For persons within the agricultural scheme, the percentages were 7·0, 11·1 and 7·9 respectively. The total of 1,121,213 persons on the registers at March 11 included 976,830 applicants for unemployment benefit or allowances and 144,383 non-claimants.

At March 11, there were 965,667 persons on the registers of Employment Exchanges in Great Britain who were out of a situation. This was 175,691 less than at February 12 and 463,418 less than at March 13, 1939. There were registered as unemployed in Great Britain 109,380 persons who were on short time or otherwise temporarily suspended from work. This was 205,692 less than at February 12 and 121,865 less than at March 13, 1939. Of workers who normally seek a livelihood by means of jobs of short duration, there were on the registers in Great Britain 46,166. This was 1,504 less than at February 12 and 20,433 less than at March 13, 1939.

In the industries for which statistics are regularly compiled by the Ministry of Labour and National Service, the changes in rates of wages reported to have come into operation in March are estimated to have resulted in an increase of 144,000*l.* in the weekly full-time wages of about 590,000 workpeople and in a decrease of 800*l.* in those of 20,000 workpeople. The 20,000 workpeople whose wages were reduced had received increases of greater amount in the first two months of the year. The principal groups of workpeople whose wages were increased were coal miners in Yorkshire, Lancashire and Cheshire, and South Derbyshire; workpeople employed in steel-melting shops and rolling mills in various districts; time-workers employed in the electrical cable-making industry; seamen; and road motor-transport workers in certain areas. The decreases affected coal miners in Leicestershire and Somersetshire. The changes reported in the first three months of 1940, in the industries for which statistics are available, are estimated to have resulted in a net increase of about 855,000*l.* in the weekly full-time wages of about 5,260,000 workpeople.

The number of trade disputes involving stoppages of work, reported to the Department as beginning in March, was 82. In addition, 15 disputes which began before March were still in progress at the beginning of that month. The approximate number of workpeople involved in these 97 disputes, including workpeople thrown out of work at the establishments where the disputes occurred, was 53,000, and the aggregate duration of the disputes in March was about 165,000 working days.

At April 1, the average level of retail prices of the commodities taken into account in the statistics compiled by the Ministry of Labour (including food, rent, clothing, fuel and light, and miscellaneous items) was approximately 78 per cent. above the level of July, 1914, as compared with 79 per cent. at March 1. For food alone, the index figure at April 1 was 58 per cent. above the level of July, 1914, as compared with 61 per cent. at March 1. The fall in the index figure for food was due mainly to a sharp decline in the prices of eggs. Among items other than food the principal changes were increases, averaging about 2 per cent., in the prices of clothing.

On Wednesday last week, the General Council of the Trades Union Congress gave further consideration to the war-time economic problems which have been the subject of discussion with representatives of the employers. A draft statement was approved and will be considered at a further conference with representatives of the employers. If and when the Trades Union Congress representatives and the employers' representatives agree on a statement of general policy, it will be submitted to the Council of Industry, whose function is to advise the Government on matters in which both sides are concerned.

Mr. George Barnes, who died recently, was one of the Labour Movement's ablest negotiators. He was elected assistant general secretary of the old Amalgamated Society of Engineers in 1896, and a year later succeeded Mr. John Anderson as General Secretary. He was prominent in the negotiations which followed the prolonged trouble in 1897, and did much useful administrative work in the years that followed. He represented, in Parliament, the Glasgow Division of Hutchesontown and Blackfriars, and took the place in Mr. Lloyd George's war cabinet which Mr. Arthur Henderson vacated.

In their second report—which was issued last week—the Select Committee on National Expenditure suggest that the whole question of competitive bidding for engineering personnel should receive the most urgent attention of the Ministry of Labour and National Service. Arising out of the shortage of engineering personnel, the Committee say, a system of "auctioneering" between one firm and another has grown up. Many advertisements have been appearing in newspapers offering bonuses and special attractions in addition to normal remuneration, and the majority of those which have been brought to the Committee's notice have been inserted by engineering firms engaged on contracts with the Air Ministry. It has also been stated in evidence, the report records, that in certain districts labour scouts are sent round in the evenings to persuade skilled workmen to leave their present jobs and to apply for work elsewhere with the promise of increased remuneration. The Committee—which intimates that it is making further investigations into the matter—adds:—"The fact that certain contractors can apparently afford to pay these extra bonuses suggests that the prices they are receiving are excessive."

The wages of women who take the places of men called up for military service is the subject of an important award issued last week by the Industrial Court. The matter was referred to the Court, after disagreement in the National Joint Industrial Council for the Road Passenger Industry, as to the rates of pay of women employed by local authorities as war-time conductors of passenger vehicles. The Court's decisions are that women employed to replace men should be over 18 years of age; that for the first six months and, until a woman conductor is 21 years of age, not less than 90 per cent. of the adult male conductor's commencing rate should be paid, and that thereafter the scale of pay and increments applicable to adult male conductors should be applicable to women. The guaranteed week for women may be reduced to 40 hours, providing that all time worked in excess of 40 hours is paid for at overtime rates.

It will, no doubt, be recalled that an agreement was recently arrived at between the National Federation of Boot Manufacturers and the National Union of Boot and Shoe Operatives regarding the employment of women on jobs in the shoe trade formerly exclusively performed by men. Where women are transferred to men's departments they will be paid a graduated scale rate for the first month and then receive the same piecework rates as the men. Women entering the industry will be registered and paid 15 per cent. below the minimum rate for the first six weeks, 10 per cent. below for the next six weeks and then the full minimum scale. Similar arrangements apply to new unskilled male workers entering the industry.

A French Decree of March 5 laid down rules for the organisation and supervision of apprenticeship in undertakings. It also contained regulations governing inspectors of apprenticeship. The departmental committees on technical education have the duty of defining the conditions of apprenticeship for each occupation or group of occupations. For this purpose they draw up apprenticeship regulations, which are subject to the approval of the Ministers of Labour and Education, after consultation with, or proposals by, the most representative organisations of workers and employers in the department; in the absence of these, the decision is taken after consultation with the arbitration committees, if they exist in the department. Persons in charge of vocational training must show that they have had at least five years' practical experience in the occupation as technicians, master craftsmen, skilled workers or skilled employees.

The inspectors whose task is to supervise the observance of the provisions in force in regard to the liabilities of employers must see that the undertaking has the required number of apprentices and young persons between the ages of 14 and 17 and must examine the conditions under which their practical and theoretical education is organised; they must supervise the observance of the apprenticeship regulations and must require each apprentice to produce to them the certificate of vocational guidance required by the Decree of May 24, 1938. The general inspectors of technical education and the members of the labour inspection service are considered as apprenticeship inspectors. These inspectors may also be recruited from other classes of persons, such as those who have taken part in commerce and industry whether as employers, engineers or technicians, or as skilled salaried employees or skilled workers.

Where the regulations and conditions of apprenticeship are not observed, the departmental committee may refuse to consider the apprentices thus trained as belonging to the number of apprentices that the undertaking must by regulation possess. The head of the undertaking may, however, apply for an expert opinion and may appeal against the decision of the committee. If, however, a measure has to be taken against the employer limiting the number of apprentices in his undertaking or suspending for the time his right to train apprentices, he is, nevertheless, bound to pay the statutory contribution for each apprentice between the ages of 14 and 17 whom he would otherwise have been entitled to engage.

Laws adopted recently in Kenya, Nigeria and the West Indian colony of St. Lucia, amend existing legislation concerning trade-union privileges. In particular, the right of peaceful picketing is recognised, as provided in United Kingdom legislation and as recommended for the West Indies by the recent Royal Commission. The laws declare it "lawful for one or more persons, acting . . . in contemplation or furtherance of a trade dispute, to attend at or near a house or place where a person resides or works or carries on business or happens to be, if they so attend merely for the purpose of peacefully obtaining or communicating information, or of peacefully persuading any person to work or abstain from working." It is not, however, lawful for persons to so attend "in such numbers or otherwise in such manner as to be calculated to intimidate any person in that house or place, or to obstruct the approach thereto or egress therefrom, or to lead to a breach of the peace."

PROBLEMS OF THE SINGING PROPELLER.*

By PROFESSOR W. KERR, DR. J. F. SHANNON, and DR. R. N. ARNOLD.

THE "singing" propeller presents one of the most disconcerting problems marine engineers have had to face in recent years. A few isolated cases seem to have been reported in the past, but in latter years the disease has become so acute that ship trials are awaited with a certain measure of anxiety. The phenomenon exhibits its unwelcome symptons in liner, merchant ship, tanker, whaler, and destroyer alike, irrespective of whether they are propelled by turbine, reciprocating, or Diesel engines, or whether they have single or multiple screws. The term "singing," when applied to a marine propeller, may be assumed to include any abnormal noise which emanates from it under working conditions. Hum, squeak, grind, squawk, rasp, twang, and saw—these are but a few attempts to convey impressions of singing to those who have not had the doubtful privilege of hearing the phenomena. The sounds may be either of musical or discordant character. Some singing propellers emit only one type of sound, but records seem to indicate that in the more common cases both types are represented.

It is now generally admitted that the singing of a propeller is the direct result of vibration of the blades. The vibration forms exhibited by a flat plate are sufficiently complex in themselves, but when a variable thickness, a non-symmetrical contour, and a helical form are introduced, the complexity is greatly multiplied. Elastic coupling effects between torsion and flexure combine to add further complications. Apart, however, from the dynamical reactions of such a blade, there exist the equally intricate hydrodynamical actions. The blade is forced to cut through a wake of variable velocity which affects the angle of incidence, thrust, and position of centre of pressure. Cavitation, trailing vortices, and cyclic speed variation finally combine to produce a problem so formidable that an infallible solution is hardly to be expected.

Only propellers of sufficient size appear capable of emitting noise and this limits the scope of any research which can be conducted with models. To confine attention to full-scale experiments demands apparatus beyond the means of normal laboratory research, and therefore most of the explanations already advanced are based on aural observations from ship trials or indirect deduction from model experiments. Ship trials, however, have only been useful in furnishing details of the noises emitted at various rotational speeds, visual observation of hydrodynamic action having up to the present proved impracticable. Any conclusions, therefore, based on such indirect evidence, must be accepted with reserve. Research on models may be open to similar criticism, but the results obtained by such methods can be of fundamental value even if their relation to full-scale phenomena may not be fully understood.

It is not surprising to find a variety of theories being advanced to account for "singing." The basic ideas underlying them are reflected in the methods proposed for the elimination of the trouble. Some of these remedies, though successful in one case, may fail in another, making the problem even more elusive. In one the trailing half of the blade is thickened, in another the centre of gravity of each blade section is arranged to lie on a radial straight line, in another the blade masses are redistributed to avoid accordant vibration, and in yet another the edge of the blade is sharpened round the leading and trailing edges and tip. These, it is believed, have been on separate occasions successful in effecting a cure.

All methods at first sight are alike in essence—that of changing the sectional form—but the principles underlying each modification are widely different. The first three methods may be taken as attempts to control the dynamical influences and the last-named as aiming to control the hydrodynamic influences. One seeks to avoid the dynamical system which is susceptible to vibrational stimulus, the other to eliminate the hydrodynamical influences which, it is believed, may cause the response. In other words, one accepts the causes and devises a system on which these causes have no effect; the other accepts the system and attempts to eradicate the causes. An appreciation of this is important in assessing the fundamental issues of singing and the value of the research already conducted.

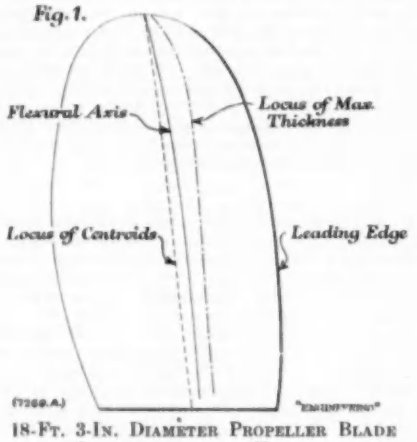
The wide range of data relating to singing and non-singing propellers of various types, made available by the courtesy of interested authorities, allowed a comparison to be made between propellers of approximately similar dimensions and design. The comprehensive list included built-up and solid propellers with symmetrical and trailing plan forms, and segmental and aerofoil blade sections. Among these were certain propellers which had been successfully modified to obviate singing. New propellers designed to replace those prone to singing were also represented.

Examination of the data suggested the grouping of propellers on a basis of plan form. They appeared to be readily divided into three main groups which are represented by the forms shown in Figs. 1, 2 and 3, on this page. The curvature of the flexural axis, the relative blade stiffness in torsion, and the positions of the effective centres of pressure and of mass relative to the flexural centre of the root section, were considered. Such characteristics were essential to a study of the possibility of blade flutter. Equal consideration was given to variations in plan form and section profile, in view of their influence on hydrodynamic action and vibrational form. Some of the more important issues arising from the above grouping may now be considered.

Group A.—The form in Fig. 2 may be taken to be representative of this group. Each propeller had a trailing plan form with a curved line of maximum thickness, the average curvature being 1·5 in 10 for the full blade and 0·7 in 10 for the outer half. The data for these propellers seemed to indicate that curvature of flexural axis and trailing plan form were not in themselves fundamental factors. A significant feature, however, became evident. The quiet propellers in this group had in general sharp leading and trailing edges.

Group B.—In this group, represented by the plan form of Fig. 1, there were ample data available from silent and noisy propellers of almost identical dimensions. It is convenient to describe briefly a series of four-bladed bronze propellers of similar plan form

Fig. 1.



18-FT. 3-IN. DIAMETER PROPELLER BLADE INVESTIGATED FOR FLUTTER.

Notes heard were 195 and 256 vibrations per second, with the higher note rising with increase of speed to about 280 vibrations per second. The table below gives the observed frequencies in vibrations per second. The first-order flexural (edgewise) vibrations occurred at 220 to 280 vibrations per second.

Order.	Flexural.	Torsional.
1	42	145
2	110	237
3	206	310
4	333	—

Fig. 2.

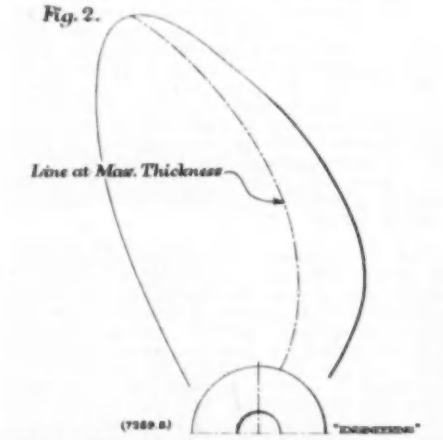
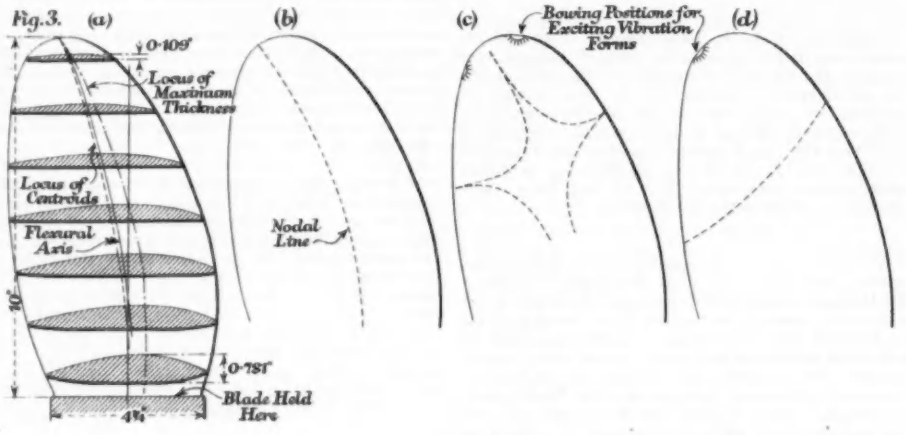
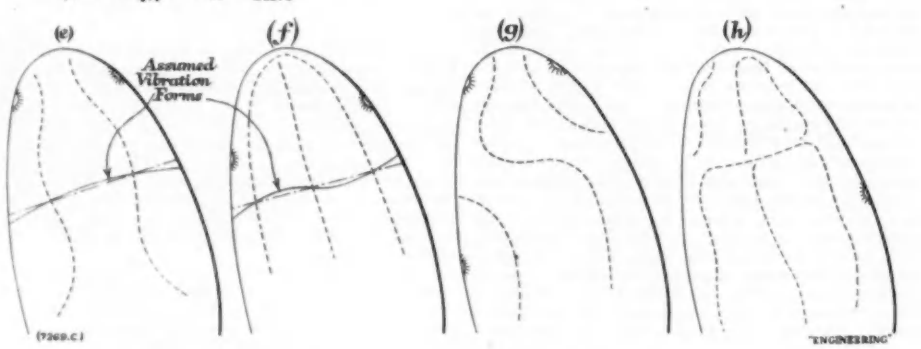


Fig. 3.





VIBRATION MODES OF MODEL PROPELLER BLADE.

All frequencies given in vibrations per second.

a Detail of model blade.
b First-order torsion. Frequencies: experimental, 737; calculated, 704.
c Second-order torsion. Frequencies: experimental, 1,280; calculated, 1,140.
d Second-order flexure. Frequencies: experimental, first-order 221, second order 610; calculated, first-order 235, second-order 627.
e Two-nodal plate. Frequency: experimental, 2,700; calculated, 2,560.
f Three-nodal plate. Frequency: experimental, 4,260.
g Three-nodal plate. Experimental frequency, 4,380.
h Experimental frequency, 3,820.

* Paper read at a meeting of the Institution of Mechanical Engineers, in London, on Friday, April 19, 1940. Abridged.

and blade area. All were of aerofoil section with rounded edges, and only slight differences existed in pitch and curvature of the line of maximum thickness. The latter varied from 0·48 in 10 to 0·94 in 10 over the blade length. Example 1 is representative of two solid propellers of 18 ft. 6 in. diameter fitted to sister ships. These propellers, of identical design, both emitted noise in service, one exhibiting severe erosion and cracking on three of the blades. In these, erosion due to cavitation extended over the leading quarter of the back of the blade between 0·8 and 0·9 of the propeller radius, while longitudinal cracks occurred on both sides of the trailing half and penetrated the section. The disposition of the cracks suggested fatigue due to the vibrational form given in Fig. 3*e*, the weaker trailing edge succumbing to the stress fluctuations. Curiously enough, the duplicate propeller, though noisy, exhibited no cracking or erosion. Example 2, a solid propeller of 18 ft. 3 in. diameter, emitted no noise in service, but was found later to be severely eroded and to have developed fatigue cracks similar to the foregoing example.

Example 3 deals with the propellers for four sister ships. These were of the built-up type, 18 ft. 3 in. in diameter, and had a plan form identical with that of Fig. 1. The torsional stiffness of the blades was slightly greater than in those described above. Slight noise was detected from the propellers of the first two ships, and those for the remaining ships were consequently modified by stiffening the outer third of the blades, the maximum thickness being increased by about 23 per cent. at 0·9 radius, and the radii at leading and trailing edges increased from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. In spite of this modification, these propellers proved to be noisy. Example 4 concerns propellers for two sister ships. Of the solid type, 18 ft. 3 in. in diameter, they were of heavier design towards the tips than those already described. Leading and trailing edges were of $\frac{1}{4}$-in. and $\frac{1}{8}$-in. radius respectively. Both these propellers were noisy in service, but were later modified by sharpening the leading, trailing, and tip edges. This effected a cure and both propellers are now working silently. This modification did not alter the line of maximum thickness, and the change in mass distribution was not serious enough to disturb the flexural axis or modes of vibration.

From the cases cited in this group many important issues emerge. The first two examples demonstrate convincingly the susceptibility of a propeller blade to lateral vibration of the form indicated in Fig. 3*e*. Such a mode of vibration appears to be easily stimulated, and in the cases cited seems to be directly associated with erosion due to cavitation at the leading edge. The proneness to singing of propellers with rounded edges is illustrated by examples 3 and 4. In the former case, stiffening the outer part of the blade and increasing the edge radii had no beneficial effect, while in the latter, a sharpening of the originally blunt edges was sufficient to counteract the singing.

Group C.—This group is illustrated by the plan form of Fig. 3*a*. A few examples were available in which sharpening of the edges had been successful in curing singing. Example *a* represents two four-bladed solid propellers of 16 ft. 6 in. diameter, built for sister ships. The curvature of the line of maximum thickness was 0·6 in 10 over the blade length, and 0·49 in 10 over the outer half. The sections, of aerofoil design, had their maximum thickness at about 0·35 of the chord from the leading edge, and the radii of leading and trailing edges were, respectively, 0·21 in. and 0·15 in. at 0·85 of the propeller radius. On trial, the propeller of the first ship emitted noise, and both propellers were therefore modified. The alteration consisted of sharpening the complete leading and trailing edges and "fining" the edge at the tip, and proved to be completely successful. Both propellers are now working silently.

Example *b* concerns a solid propeller, 16 ft. in diameter. Its plan form is shown in Fig. 3*a*. The curvature of the line of maximum thickness was 0·88 in 10 on the blade length and 0·66 in 10 on the outer half. This propeller proved noisy and was altered by sharpening the leading edge and cutting a portion off the tips. The tips were left abrupt and blunt, and a further trial showed no improvement. The final modification, carried out by Messrs. The Manganese Brass and Bronze Company, Limited, consisted, it appeared, in correcting and fining the tip, together with sharpening the trailing edge. In addition, some material was removed from the back of the blade, thus altering the mass distribution. This propeller is now reported to be running silently. Example *c* is that reported by Troost in the discussion on Hunter's paper before the North East Coast Institution in 1937. The propeller was modified by converting the aerofoil sections at the tip into those of sharp-edged segmental type. Such proved to be completely successful, though experience seems to show that a slight wash-away at the face of the leading edge is advisable on segmental sections in order to minimize the possibility of face cavitation.

The examples of this group indicate the importance of correct tip and edge design. Sharpening at the edges appears to be beneficial as a cure for singing, though example *b* demonstrates that this in itself is not a sufficient cure if the tip is badly designed. It is shown later that a blunt tip is associated with the production of strong tip vortices, and it is thought that these were responsible for the singing after the first modification in example *b*.

Wake.—Directional flow and viscous forces produce at the stern a water stream in which the flow is far from uniform, some regions even tending to approach the velocity of the ship. To appreciate the influence of wake variation, Fig. 4, on this page, has been constructed. It shows by means of velocity vectors that the angle of incidence of the blade is greatly increased when it passes through a high wake. This result, however, is by no means isolated. Thrust, torque, pressure distribution, centre of pressure, stalling, and cavitation, are all dependent on the incident angle, and therefore indirectly affected by the wake. Somewhat similar effects may also result from cyclic speed variation of the propeller, and the change in angle of incidence due to this is illustrated for comparison in Fig. 5.

Cavitation.—The phenomenon of cavitation is associated with the existence of low-pressure regions in a fluid. These regions may be the result of high suction on the blade or the formation of powerful vortices. When the critical pressure is reached, bubbles or cavities form in the fluid and if motion is present these will collapse on entering a region of higher pressure. When a blade element passes through a fluid it is subjected to a certain pressure distribution. As an example of this, the aerofoil section shown in Fig. 6, on this page, may be taken. The authors' observations show that the actual commencement of cavitation may be observed as an opaque halo surrounding the leading edge of the blade, composed, no doubt, of innumerable cavities of microscopic dimensions. In a later stage, this gives place to visible bubble formation with subsequent collapse. The collapsing of the cavities subjects the blade to a series of water-hammer impacts of very high local intensity and these, in time, produce erosion and pitting on the metal surface.

Vortices.—The vortices resulting from propeller action are of two forms, namely, trailing vortices and tip vortices. The former originate at the trailing edge of the blade and have a frequency dependent on the speed of advance and the projected area in the direction of motion. The energy content of such vortices is relatively small and consequently their existence is not manifested by any vortex cavitation. The tip vortex, however, has a much more violent action and often is so powerful that cavitation occurs. What action this vortex may have on the blade is not at present entirely understood, but it may react on the tip of the blade and so incite vibration.

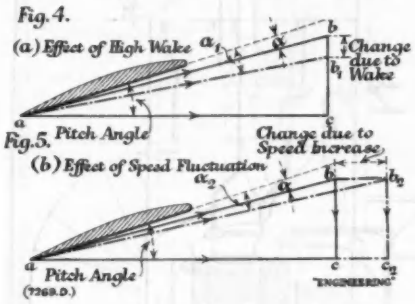
Dynamical Features: Modes of Vibration.—A propeller blade may be set in vibration in a large number of ways, each associated with a particular frequency. More than one mode may exist at the same time, resulting in the emission of a variety of notes. In such a case the vibrational forms are superposed on each other. Fig. 3 illustrates some of the vibration patterns of a typical propeller blade, the simplest ones being flexural and torsional vibration similar to that of a cantilever beam. In addition to this general type of vibration, the relatively thin parts towards the tip readily vibrate in a manner similar to that which occurs in a thin plate. Probably the most easily excited of this type of vibration is that indicated in Fig. 3 *e* and *f*, which show, respectively, two and three nodal lines running longitudinally along the blade. These types arise from excitation at the leading and trailing edges of the blade.

The frequencies of the grinding and humming noises which are heard coming from propellers vary from about 170 to 700 per second. This range renders it difficult to correlate the frequencies heard with the corresponding modes of vibration. For instance, with a 16-ft. diameter singing propeller, the examination of which is recounted later, the frequency range of the noise includes the third to the sixth modes of flexural vibration normal to the blades, the first edgewise flexural vibration and the third and fourth in torsion. In addition, the plate vibration indicated in Fig. 3 *e* to *h* also came within the scope of the noisy frequencies.

With a typical blade of aerofoil section, the flexural modes may be interlinked with the torsional modes by means of various couplings. The simplified system given in Fig. 7, herewith, illustrates these couplings. It represents an element of a blade, the centre of mass of which is supposed to be concentrated at G, and offset from the flexural axis O T. This axis is such that a force applied normal to the section on the axis will only cause bending. If, however, the force is applied on either side of the axis, the blade will twist in addition to bending. Hence, with the centre of mass eccentric to the axis, flexural vibration will be accompanied by torsional vibration due to the inertial coupling. If the centre of pressure of the fluid forces on the blade is forward of the flexural axis, torsional deflection will occur and consequently a change in lift force will ensue, causing additional bending and twisting. A condition of static instability is possible if the flexural axis is so far aft that the fluid torque becomes greater than the torsional elastic torque. A further coupling arises, due to the flexural velocity of the blade virtually inducing a change in angle of incidence of the fluid stream, thereby inducing a variable torque if the centre of pressure is offset from the flexural axis.

It will be evident that, when a disturbance comes on the blade from any source, vibration tremors in the various modes will ensue. Naturally, with a sensitive

Fig. 4.



EFFECT OF HIGH WAKE AND SPEED FLUCTUATION.

	Steady Flow.	High Wake.	Speed Increase.
Velocity of blade relative to water	$\overline{a\,b}$	$\overline{a\,b_1}$	$\overline{a\,b_2}$
Velocity of blade relative to ship ..	$\overline{a\,c}$	$\overline{a\,c}$	$\overline{a\,c_2}$
Velocity of water relative to ship ..	$\overline{b\,c}$	$\overline{b_1\,c}$	$\overline{b_2\,c_2}$
Ideal angle of incidence	α	α_1	α_2

Fig. 6.

Fig. 7.

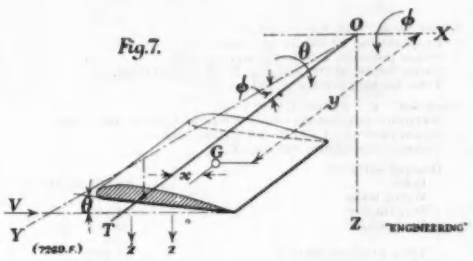
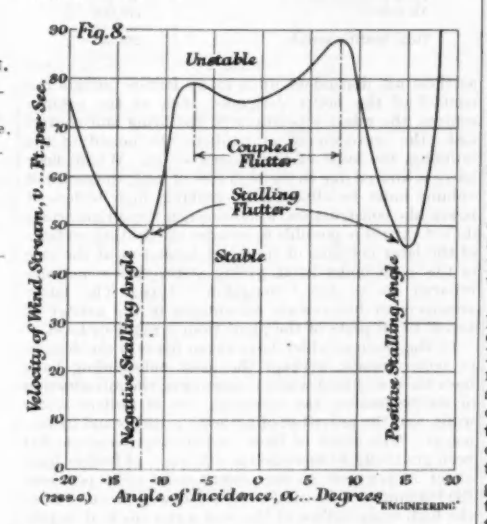


Fig. 8.



dynamical system which is moving in a fluid stream, the possibility of flutter suggests itself. Flutter is a self-maintained vibration which involves at least two coupled modes of vibration such as flexure and torsion, in which the energy maintaining the vibration is obtained from the fluid stream. The fluid forces are controlled by the coupled motion, and their change from positive to negative damping at the critical speed, marks the commencement of coupled flutter.

This type of flutter occurs only at small positive and negative angles of incidence and is not to be confused with stalling flutter, which can occur with the angle of incidence near the positive or negative stalling angle. At stalling there is irregular turbulent eddying, and with vibration present, the fluid forces are subject to a considerable hysteresis effect. A self-induced vibration readily manifests itself at the positive or negative stalling angles and it can exist with only one degree of freedom. It can also occur with bending and torsion in phase. In Fig. 8, herewith, are shown the flutter speeds for a system over a range of angles of incidence and it will be seen that stalling flutter can occur at a much lower speed than coupled flutter. On this account, stalling flutter is considered to be serious if conditions arise which cause stalling on the outer part of the blade. Like coupled flutter, it is also influenced by blade stiffness and damping, and to a certain extent by the blade sections.

(*To be continued.*)

FORTY YEARS' DEVELOPMENT IN MECHANICAL ENGINEERING PLANT FOR POWER STATIONS.*

By SIR LEONARD PEARCE, C.B.E., D.Sc.

(*Continued from page* 424.)

BOILER plants afford one of the most striking examples of increase in capacity over the years, and the gradual and regular steps in which this has taken place tend to mask its full significance. It is interesting therefore, to compare one of the 12,000-lb. per hour boilers installed at Stuart-street, Manchester, in 1902, with one of the latest 550,000-lb. per hour boilers at present being installed in the Battersea "B" station. Figs. 32 and 33, herewith, show a cross-section through these two units to the same scale. The need for larger boilers has, of course, followed the increase in size of the prime movers, but it has been accentuated by the tendency to reduce the number of boiler units per turbine. In the United States this has been carried as far as the provision, for each turbine, of a single boiler capable of providing the whole of the steam required up to the maximum continuous load on the turbine. This practice is by no means universal there, however, and up to the present there is no example in this country. Such a scheme envisages an availability factor for the boiler comparable with that of the turbine, but statistics and operating experience do not, in general, appear to justify such an assumption as yet. A reasonable compromise in capital expenditure and continuity of supply appears to be attained by providing two boiler units per prime mover, so rated that their individual economic outputs are about 50 per cent. of the total steam demand of the turbine at full load and their maximum continuous ratings are such that about 65 per cent. of the full load of the turbine can be carried on one boiler only. There are, however, usually other factors which have to be taken into consideration, such as space available, total number of turbine units, the extent of interconnection to be provided, etc.

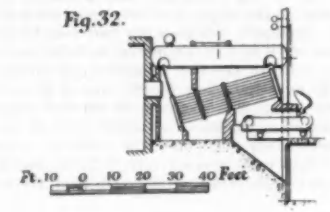
Table X, on the opposite page, shows a representative list of large boilers in this country and in the United States. Size is by no means the only consideration to be borne in mind by boiler designers, and the continual rise in steam pressures and temperatures has materially altered the heat quantities and temperature differences involved. Figs. 34 and 35, above, graphically illustrate this point, as well as the continual reduction in latent heat and growing importance of superheat, and the diminution in effective temperature differences. These factors, together with the greatly increased use of radiant heat by the adoption of water walls, have revolutionised boiler design to the extent that the "boiler," as such, has become a gradually decreasing proportion of the whole plant, and in certain designs is little less than a screen of widely pitched tubes.

In all types of boilers an increase in evaporative capacity has been accompanied by a reduction in space occupied, due to improvements in design following on increased knowledge of heat transfer and combustion problems. No definite figures can be given for the areas and volumes required for given boiler outputs,

* The 26th Thomas Hawksley Lecture, delivered before the Institution of Mechanical Engineers, in London, on Friday, January 19, 1940. Abridged.

MECHANICAL ENGINEERING IN POWER STATIONS.

Fig. 32.



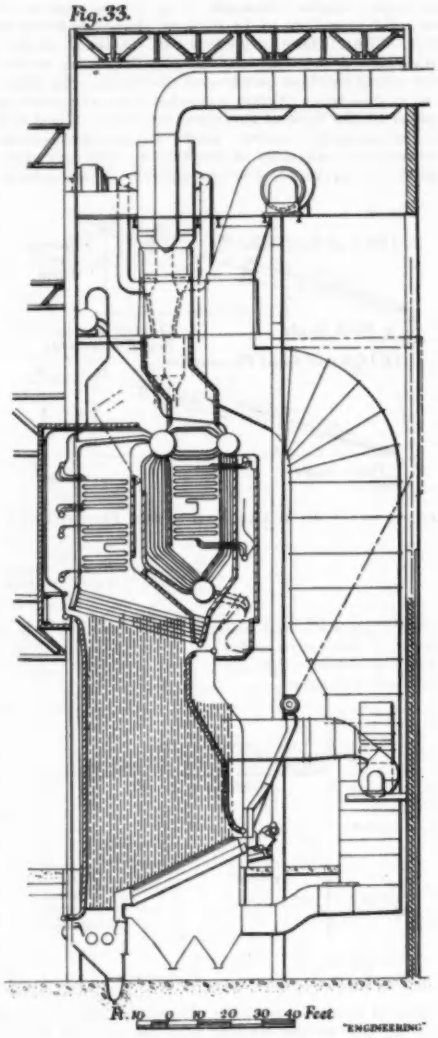
Stuart Street, Manchester (1902) :—
Evaporation, 12,000 lb. per hour.
Steam pressure, 150 lb. per square inch.
Steam temperature, 366 deg. F. (dry saturated).
Total heating surface, 3,580 sq. ft.

Battersea "B" Station (1940) :—
Maximum continuous evaporation, 550,000 lb. per hour.
Steam pressure, 1,420 lb. per square inch.
Steam temperature, 965 deg. F.

Heating surface :—

Boiler	18,603 sq. ft.
Water walls	4,737 "
Superheater	14,540 "
Economiser	20,713 "
Total pressure surface	58,593 "
Air heater	170,000 "
Total heating surface	228,593 "

Fig. 33.



as these are dependent upon many factors outside the control of the boiler designers, such as the column centres, the relative positions of the firing and control aisle, the arrangement of bunkers, the height of the building, the type of firing, and so on. Where floor space is limited due to the high cost of land, the required volume must be obtained by building high boilers of tower-like construction, whereas when these limitations do not exist it is possible to arrange the heating surfaces of the later portions of the plant behind or at the side of the main boiler itself, giving a structure sometimes referred to as the "bungalow" type. The latter arrangement has certain advantages in the matter of access to all parts of the plant from firing-floor level.

Of the changes which have taken place in the designs of boiler plants, perhaps the most outstanding have been the use of feed-water economisers, the introduction of air preheating, the increasing use of radiant water walls, and the provision of accurate controls and instruments. The result of these various improvements has been gradually to increase the efficiency of boilers from about 70 per cent. to the present order of 90 per cent. Bled-steam feed heating involved new problems, since the high temperature of the feed water made it impossible to reduce the temperature of the outgoing gases sufficiently to ensure minimum chimney losses. This led to the introduction of air preheating. The gases, after leaving the economiser, pass through an air preheater where their temperature is reduced to a low figure. The heat thereby recovered is absorbed in the combustion air. Various forms of preheaters have been developed, such as the tubular, plate, and rotary regenerative types. There are suitable fields of application for each, but where space is important, the regenerative type offers considerable advantages.

The design of combustion chambers has altered very considerably. The early type had a small space lined with refractories between the grate and the boiler tubes, whereas a large chamber provided with very extensive water-cooled walls is now common; Figs. 32 and 33 illustrate this. Full advantage is taken of the radiant heat of the fuel bed and flame to absorb a large proportion of the heat of combustion, the present tendency being to work to energy-release rates of the low order of 20,000 to 30,000 B.Th.U. per hour per cubic foot of furnace volume. The water walls may be of various designs, such as bare tubes, fin tubes, or cast-iron block-covered tubes. It is with the object of obtaining high availability factors that low heat-release rates and almost entire elimination of refractories in the combustion chamber have been developed.

I have indicated in Figs. 34 and 35 the gradual increase in superheat per lb. of steam which has resulted from the adoption of higher steam temperatures; it follows that the amount of superheat surface required has increased correspondingly. Furthermore, its location in relation to the other pressure parts has been modified very considerably, this surface being gradually brought nearer and nearer to the furnace to compensate for the reduced available temperature head. Correspondingly, there has been a great reduction in boiler heating surfaces in front of the superheater. Thus we have passed through the phases of the superimposed superheater (on the boiler outlet) to the integral superheater (provided at an intermediate stage), and then to superheaters arranged almost at the furnace outlet, the latter being partly of the radiant type. Some superheaters have been installed in the walls of the combustion chambers, and it is claimed that a combination of such a unit, operating in series with a convection superheater, gives a flat total-temperature characteristic over a wide range of load.

The increase in superheat temperatures to a point approaching that at which the physical properties of the materials may be affected has brought into prominence the question of superheat control. This can be achieved in a number of ways, such as the radiant-convection combination referred to, desuperheaters between the two sections of the superheater, or by-pass dampers to control the gas flow through the superheater according to load. The increased use of water walls and the greater proportion of superheater surface have combined to reduce very considerably the pure convection boiler heating surface required for a given output, though in natural-circulation boilers some such surface and the drum, or drums, for it are required.

There are two main types of boilers, straight-tube header and bent-tube. The general inclination appears to be towards the use of the latter, at any rate for the very large boilers working at the higher pressures. The latest 550,000-lb. per hour boilers for Battersea constitute a combination of both types. In this design, which is of the natural-circulation type, particular attention has been given to the securing of satisfactory water circulation in view of the operating pressures to be adopted. Towards this most desirable end the importance of unheated down-tubes cannot be over-emphasised. A further feature is the installation of a dry-steam drum, which removes any possibility of trouble from the creation of foam due to the mixtures of steam and water in the lower drums.

One of the latest developments in the straight-tube header type of boiler with natural circulation is the "high head" unit. A typical example is the pulverised-fuel fired 160,000 lb. to 182,000 lb. per hour Babcock and Wilcox boiler at the Upper Boat station of the South Wales Power Company. Four of these boilers are being supplied and they are designed to produce

MECHANICAL ENGINEERING IN POWER STATIONS.

Fig. 34. *Actual Heat Quantities (B.Th.U.)*

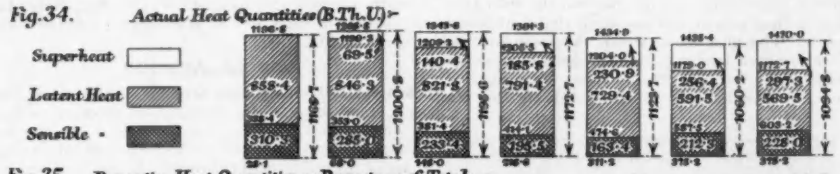
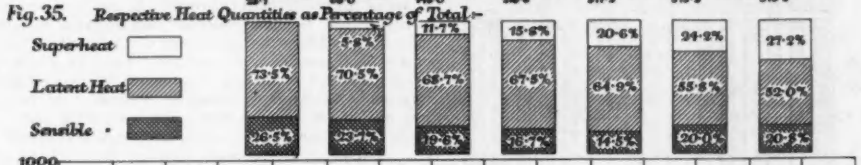
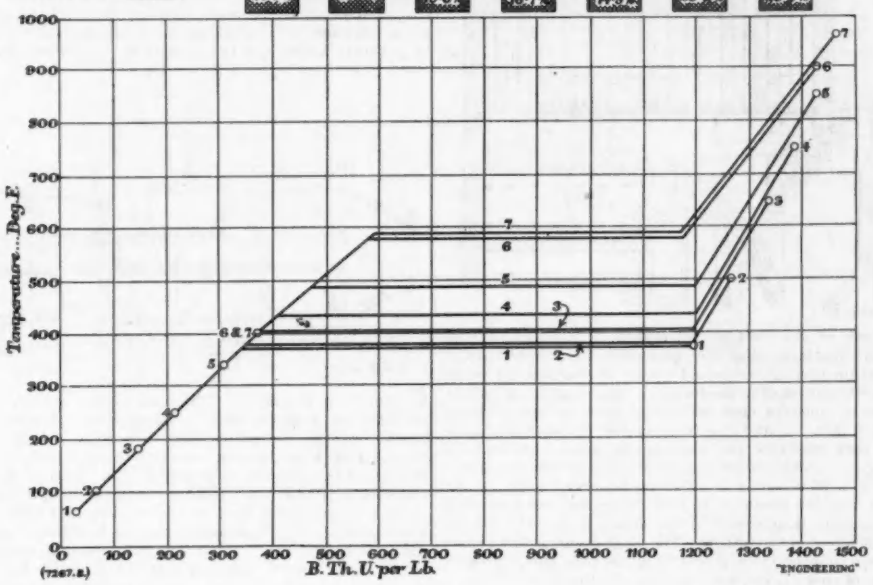


Fig. 35. *Respective Heat Quantities as Percentage of Total*





Terminal Conditions :—	1.	2.	3.	4.	5.	6.	7.
Steam pressure, lb. per square inch gauge ..	150	180	250	350	600	1,300	1,420
Final steam temperature, deg. F.	366	500	650	750	850	900	965
Saturated steam temperature, deg. F.	366	380	406	436	489	579	590
Feed temperature, deg. F.	60	100	180	250	340	400	400

TABLE X.—LIST OF LARGE BOILERS INSTALLED OR ON ORDER.

Date.	Station.	Operating Company.	No. of Boilers.	Capacity. Lb. per hr.	Steam Pressure. Lb. per sq. in.	Steam Temperature. Deg. F.	Feed Temperature. Deg. F.	Method of Firing.
	Great Britain.							
1937	Battersea "B"	London Power Co.	2	550,000	1,420	965	400	Retort stoker
1935	Battersea "A"	London Power Co.	3	375,000	625	875	355	Retort stoker
1937	Deptford West	London Power Co.	1	350,000	375	780	240	Retort stoker
1938	Hams Hall "B"	Birmingham Corporation	4	350,000	670	845	340	Pulverised fuel
1928	Battersea "A"	London Power Co.	6	312,000	600	830	355	Retort stoker
1938	Little Barford	Beds, Cambs, and Hants Public Supply Co.	3	300,000	675	910		Pulverised fuel
1936	Deptford West	London Power Co.	2	300,000	375	780	240	Retort stoker
1934–6	Hams Hall "A"	Birmingham Corporation	3	300,000	375	730	306	Pulverised fuel
1936–9	Hams Hall "A"	Birmingham Corporation	6	300,000	375	730	306	Chain grate
	United States of America.							
1929	East River	Consolidated Edison Co.	3	1,250,000	400	725		Pulverised fuel
1937	Logan	Appalachian Electric Power	1	1,000,000	1,425	925	383	Pulverised fuel
	Hell Gate	Consolidated Edison Co.	2	1,000,000	265	700		Pulverised fuel
1940	Oswego	Central New York Power Co.	1	900,000	1,350	900		Pulverised fuel
1938–9	River Rouge	Ford Motor Works	2	900,000	1,400	925	406	Pulverised fuel
1938	Windsor	Ohio Power Co.	2	750,000	1,475	925	395	Pulverised fuel
	Kips Bay	New York Steam Corporation	1	750,000				Pulverised fuel
	River Rouge	Ford Motor Works	2	700,000	1,400	925		Pulverised fuel
1935	Port Washington	Wisconsin Electric Power Co.	1	690,000	1,390	750		Pulverised fuel
1938	Schuylkill	Philadelphia Electric Light and Power Co.	2	660,000	1,350	910	390	Pulverised fuel
1938	Essex	Public Service Electricity and Gas Co.	2	605,000	1,475	950	299	Pulverised fuel
1935	Richmond	Philadelphia Electric Light and Power Co.	2	600,000	425	850	312	Pulverised fuel
1938	Springdale	West Pennsylvania Power Co.	3	575,000	1,450	935	425	Pulverised fuel
1937	Williamsburg	Williamsburg Power Plant Co.	2	575,000	925	830	380	Pulverised fuel
	C. R. Huntley No. 2	Buffalo General Electric Co.	4	560,000	425	750		Pulverised fuel
1935	Burlington	Public Service Electric Light and Gas Co.	1	550,000	700	850		
1940	Twin Branch	Indiana and Michigan Electricity Co.	1	550,000	2,400	940		Pulverised fuel
1932	Hudson Avenue	Brooklyn Edison Co.	8	500,000	440	750	270	Retort stoker
1938	Louisiana	Gulf States Utilities Co.	2	500,000	650	750		Gas
	San Francisco	Pacific Gas and Electricity Co.	3	500,000	1,350	750		Oil and gas
	State Line	Chicago and District Gas and Electricity Co.	4	500,000	1,400	835		Pulverised fuel
1937	Waterside	Consolidated Edison Co.	4	500,000	1,400	900	386	Pulverised fuel

steam at 650 lb. per square inch and 850 deg. F. It is claimed that the complete Bailey furnace ensures maximum furnace temperatures and consequently flexibility and high efficiency over a wide range of load. Automatically-controlled gas by-pass dampers regulate the final steam temperature within close limits. An interesting double-banked bent-tube boiler is the 1,000,000-lb. per hour boiler for the Logan station of the Appalachian Electric Power Company, designed for 1,425 lb. per square inch pressure and 925 deg. F. Automatic combustion control has been developed to a high stage, although it is arguable whether, in the case of stations operating at a high load factor, efficiencies at least comparable cannot be equally well secured with manual control.

(To be continued.)

GUIDES TO SOURCES OF SPECIALIST INFORMATION.

THE primary purpose of the Association of Special Libraries and Information Bureaux is to act as a clearing house for sources of information. One of its early activities was the compilation and publication of *The Aslib Directory*, which is a guide to sources of specialised information throughout the British Isles. Its purpose is not to give information, but to tell where it may be found. A book of this type naturally requires revision at reasonable intervals, and the Council of the Association has had the preparation of a revised edition under consideration during recent years. Quite apart from other difficulties, however, it is clear that the present is not a suitable time for the publication of an extensive book of this type. Owing to the suspension of various activities and the removal of the headquarters of libraries and information departments to temporary addresses, it is probable that such a directory correctly compiled at the present would be found seriously inaccurate in a relatively short time. In spite of this difficulty, however, the type of service rendered by such a directory is of even greater value under present conditions than normally. New activities and new interests are being imposed on workers of all kinds, calling for access to new sources of information.

The Association of Special Libraries and Information Bureaux is proposing to deal with this situation by the issue of what it has termed War-Time Guides to British Sources of Specialist Information. Each guide will cover a group of related interests, examples being Transport, including Road and Rail Engineering; and Electrical Engineering and Allied Industries. The first to be published will be concerned with Fuel and Allied Interests, and will cover coal, gas and oil technology. The guides will be compiled with the aid of specialist organisations and will each contain a preface reviewing the subject; a list of the principal sources of information; a list of technical periodicals and annuals, with notes indicating those which publish abstracts; and a subject index. The guides will probably be issued in mimeographical form; this will allow of periodic revision without undue expense. Although the date of publication of the first guide is not yet settled, it is hoped that it will not long be delayed. The guides will be on sale, the price to members of the Association being smaller than that to outsiders. The address of the Association is 31, Museum-street, London, W.C.1.

CATALOGUES.

Dust Removal.—Messrs. Keith Blackman, Limited, Mill Mead-road, Tottenham, London, N.17, have sent us a new publication dealing with fans for dust removal.

Reflux and Penstock Valves.—Messrs. Ismailia Valve Company, 17, Victoria-street, London, S.W.1, have sent us a booklet giving particulars of their reflux valves and penstocks.

Lighting System.—We have received from Messrs. Keates and Company (Electrical), Limited, 91-93, Bishopsgate, London, E.C.2, a booklet describing the Faraday-Megaphos system of lighting.

Fluorescent Lighting.—Messrs. The British Thomson-Houston Company, Limited, Crown House, Aldwych, London, W.C.2, have issued a pamphlet and folder dealing with their new 80-watt Mazda fluorescent lamp, which, it is stated, gives light of daylight quality from its entire surface.

A.R.P. Shelters and Piping Repairs.—Messrs. The Stanton Ironworks Company, Limited, near Nottingham, have issued a booklet, of convenient size for the pocket, describing some of the war-time uses of Stanton products. The publication deals with emergency repairs to pipe mains, and with A.R.P. shelters of cast iron and reinforced spun concrete.

Electromagnetic Relays.—A new design of double-acting electromagnetic relay is described in a leaflet recently sent us by Messrs. Londex, Limited, 207, Anerley-road, London, S.E.20. It is specially designed for use as an interlocking, or latch-in or out, relay in connection with the remote control of motor starters and on emergency-lighting circuits.

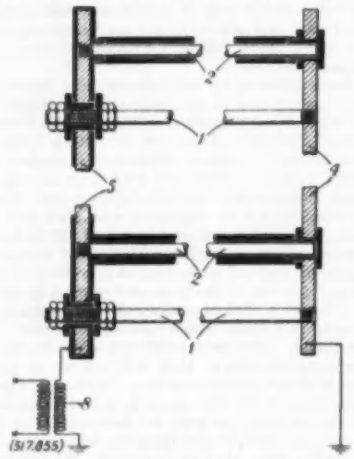
"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.
Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.
The date of the advertisement of the acceptance of a Complete Specification in each case, is given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

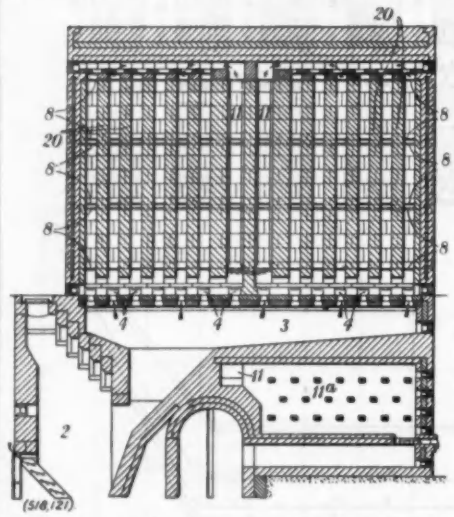
517,855. Removing Electrostatic Charges. The English Electric Company, Limited, of London, and W. E. M. Ayres, of Stafford. (1 *Fig.*) August 12, 1938.—The invention is an apparatus for removing the electrostatic charges produced on paper and textiles during manufacture. The apparatus removes the static charges by ionisation of the surrounding air and can safely be handled by the operatives, no bare high-tension conductors being employed. A grid is located close to the material, and consists of a number of parallel conductors 1 and 2. The conductors 1 are round rods each screwed at one end into a metal bar 4. The other ends of these rods pass through insulating bushes in another metal bar 5; these ends are screwed to take nuts which hold the bars 4 and 5 together. The rods 2 are screwed at one end into the bar 5 and their other ends are insulated from the bar 4 by bushes. The high and low



potential conductors alternate, and the bars 4 and 5 constitute 'bus bars. The bar 4 is connected to earth and the bar 5 to the high-tension winding of a transformer 8. The rods 2 and the bar 5 are entirely insulated. The insulation is moulded directly on to the conductors 2 and 5 so as to eliminate any air film between conductor and insulation which would lead to a reduction in the potential gradient at the outer surface of the insulation with consequent reduction of the ionisation of the surrounding air. The regulation of the transformer 8 is poor so that upon accidental short circuit the output voltage is low, as in discharge-tube lighting. The grid can be located beneath the material to be discharged so that the latter rubs over it. The action of the device depends on the high voltage gradient between the conductors and the material, which is highest in the air gap. (*Accepted February* 9, 1940.)

GAS ENGINES, PRODUCERS, HOLDERS, ETC.

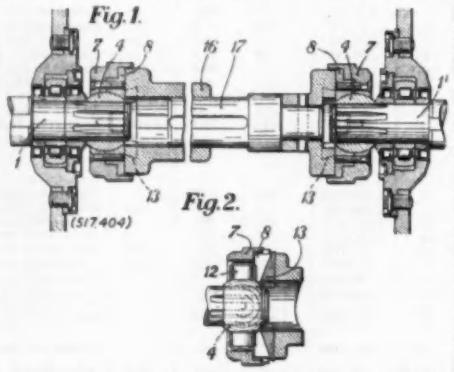
518,121. Coal-Gas Retort Setting. Drakes, Limited, of Halifax, and M. Thompson, of Halifax. (5 *Figs.*) June 15, 1938.—The object of the invention is to arrange the retorts, the producer and the flues for the gas, waste gases and secondary air so that their efficiency, as well as their economy in the utilisation of the heat of the waste gases, allows the latter to be withdrawn at a temperature sufficient for the production of steam for operating subsidiary plant in the works. The producer 2 is below the ground level, so that the gas can be conducted into a mixing chamber 3 beneath the setting. Thence the producer gas is fed into other chambers 4, into which secondary air is conveyed. The secondary air mixes with the producer gas and combustion takes place, the products of combustion rising in streams which divide to flow over the outside of two sets of retorts 8 supported by transverse walls 20, both streams reuniting at the top and entering longitudinal flues, along which they travel to the central passages 11. The heated gases thus burnt in contact with the vertical walls of all the retorts effect the distillation of the coal in them. The spent gases flow down the vertical flues 11 and enter chambers 11*a* beneath the setting. These chambers are adjacent to four inlet flues for the secondary air, which is thus heated and passes to the combustion chambers 4. The flues along which the secondary air travels are arranged two in the centre and two near the outer walls of the setting. The air inlets are controlled by dampers. The retorts, which extend for the full



length of the setting, are narrow in comparison with their depth, so that the comparatively narrow strip of coal in each is carbonised evenly throughout its whole length and width, producing a fine quality of benzol. The combustion chamber temperature is approximately 1,350 deg. C., and the temperature of the waste gases as they pass into the main flue is approximately 1,150 deg. C. With an efficient waste-heat boiler this gas is capable of raising 4 lb. of steam for every pound of fuel put into the producer, so that the works' steam requirements are largely met by the steam produced from the waste heat of the setting. The plant occupies less ground space than previous plants with the same daily throughput of coal. (*Accepted February* 19, 1940.)

MACHINE AND OTHER TOOLS, SHAFTING, ETC.

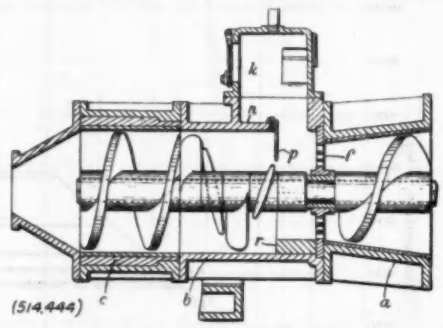
517,404. Universal Coupling. The Mining Engineering Company, Limited, of Worcester, and M. S. Moore, of Malvern. (4 *Figs.*) August 2, 1938.—The coupling is self-locking and is designed primarily for use in coupling the driving shaft and the loader shaft of a coal-cutting and loading machine, where very little space is available between the respective shaft ends and provision must be made for axial movement relative to each other. The shaft ends 1, 1′ which are to be coupled are splined and on the splined portions are fitted balls 4, secured in position by



set screws and locking screws. The balls are engaged by a spherical socket made in two parts 7, 8 connected by screws. In the socket are two diametrically-opposed slots in which slide rectangular blocks (Fig. 2). A pair of trunnions 12 on the ball rotate in the blocks. With this arrangement, the socket can turn on the ball about the trunnions 12, while movement in a plane at right angles is permitted by the sliding of the blocks in the slots in the socket. The end surface of the part 8 has undercut dogs 13 so that the socket forms a universally-mounted jaw. A co-operating jaw is formed on a sleeve 16 which slides on splines on a short shaft 17 between the shaft ends 1, 1′. The shaft 17 and the sleeve 16 form an expansible coupling which is inserted between the shaft ends 1, 1′, the jaws then being brought into engagement with the jaws 13. When a torque is applied to one shaft all the parts are locked together by the engagement of the undercut dogs and they remain in locked position so long as driving proceeds. The coupling provides a firm connection between two shaft ends which are 20 deg. or more out of alignment. (*Accepted January* 29, 1940.)

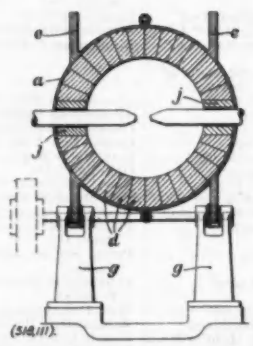
MISCELLANEOUS

514,444. Clay-Extruding Machine. Tyne Metal Company, Limited, and G. Robson, of Hexham-on-Tyne. (2 *Figs.*) May 5, 1938—The machine is of the kind having a vacuum chamber for de-airing the clay, and the object of the invention is to prevent the clay from accumulating in the vacuum chamber and blocking it. The machine consists of a conical pipe *a* attached to one end of a central casting *b*, at the opposite end of which is a second pipe *c*, terminating in a nozzle, the several parts forming a continuous passage. Plastic clay from a pug mill is fed into the pipe *a* and travels forward on a screw which forces it through an extrusion grid *f* in the smaller end of the pipe. Beyond the grid, the clay passes through the central casting *b*, where it is cut up by a rotary knife, and the minced clay is consolidated



by a screw in the pipe *c*. The screws and the knife are mounted on a continuously rotating shaft. Suction is applied to the central casting through a chamber *k* provided with inspection windows through which the passage of the clay can be watched. The bottom of the chamber *k* is partially closed by a semi-circular baffle plate *n* which forms part of the passage in which the knife revolves. The baffle plate extends to within a short distance of the grid *f*, and carries shredding teeth *p* which break up the layer of clay which forms in the way of the knife blades and tends to travel back towards the grid and cut off the suction. On the bottom of the passage through the central casting is a semi-circular baffle sill *r* which extends from the grid to about the plane of the teeth *p*. The forward end of the sill forms a sharp step which prevents the layer of clay from travelling backwards and obstructing the grid.—(*Accepted November* 8, 1939.)

518,111. Electric Furnace. Birmingham Electric Furnaces, Limited, and A. G. E. Robiette, of Birmingham. (3 *Figs.*) September 21, 1938.—The furnace is of the electric-arc rocking type, and the invention is a mode of construction which increases the life of the refractory lining and enables it to be readily repaired. The outer metal shell of the furnace consists of two parts *a*, each of hemispherical shape, bolted together. The refractory lining consists of segmental bricks *d* of uniform shape keyed to the wall of the shell to form a spherical furnace



chamber. Track rings *e* attached to the exterior of the shell enable the furnace to be rocked by rollers carried on pedestals *g*. The carbon electrodes pass horizontally through bearings *j* embedded in the refractory lining at opposite poles of the shell and are located so that the arc is at the centre of the furnace. A charging aperture and a pouring spout are provided in one segment of the shell. Thus all parts of the refractory material are subjected to the same degree of wear, while the bowl shape enables a strong lining to be provided, since it can be effectively keyed and supported in position. (*Accepted February* 16, 1940.)